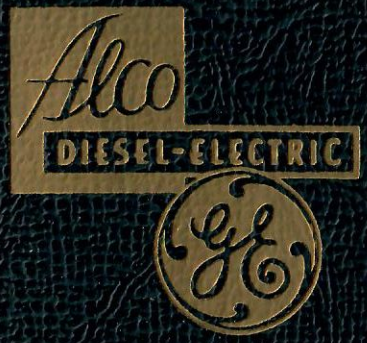
OPERATION
AND
SERVICE
MANUAL



660-HP SWITCHER

1000-HP SWITCHER

1000-HP ROAD SWITCHER

AMERICAN LOCOMOTIVE COMPANY
GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

OPERATION
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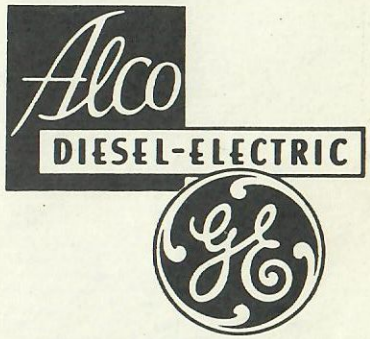

ERIE DIESEL TRAINING CAR #10

ERIE

660-HP SWITCHER

1000-HP SWITCHER

1000-HP ROAD SWITCHER

AMERICAN LOCOMOTIVE COMPANY
GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

OPERATION AND SERVICE MANUAL

TP-600

This manual covers operation and service of the standard 660 HP switcher, 1000 HP switcher and 1000 HP road switcher locomotive.

The purpose of these instructions is to explain how to efficiently operate and service the locomotive at maximum efficiency and minimum expense.

Numbers given in text or illustrations are for reference only and are not to be used for ordering renewal parts.

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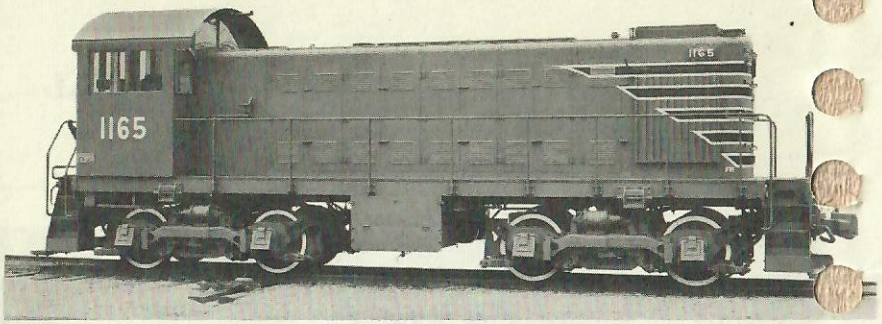
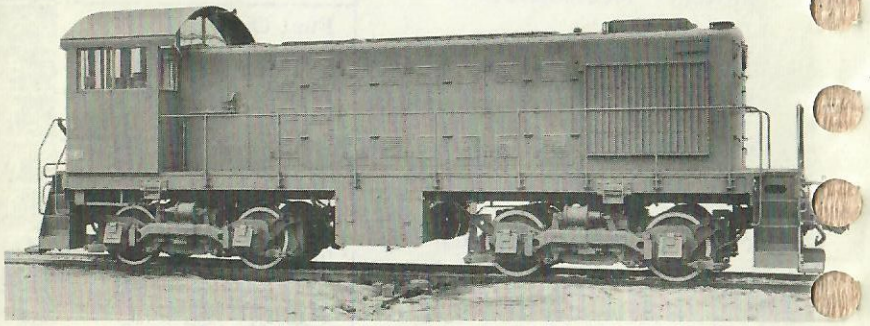
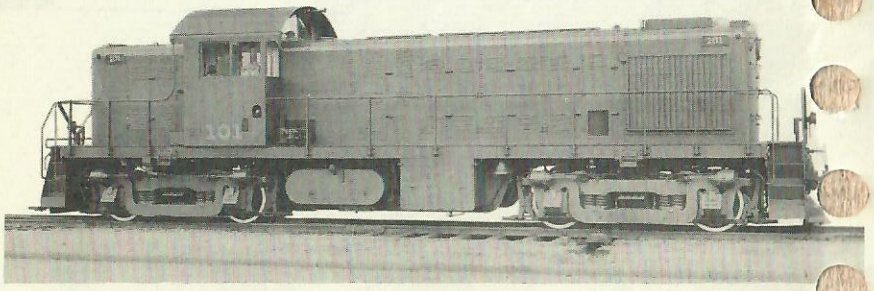


660 — HP SWITCHER



1000 — HP SWITCHER



1000 — HP ROAD SWITCHER

0 & 1

OPERATION

GENERAL DESCRIPTION

LOCOMOTIVES

Diesel-electric locomotive design is simple — a Diesel engine drives a direct-connected generator that supplies electric power through suitable control devices to traction motors mounted on the locomotive trucks.

Switcher locomotives, using either a 660 BHP or a 1000 BHP Diesel engine, are designed primarily for yard work. Road switcher locomotives, using a 1000 BHP Diesel engine, are designed for freight, passenger and switching service. Controls may be applied for multiple-unit operation of two or more units controlled from one cab.

The engine and generator, built as a unit assembly, are mounted on an underframe of built up welded steel construction.

Two four-wheel trucks having a total of four traction motors carry the entire weight of the locomotive.

The operating cab on the switcher is at the rear end of the locomotive while on the road switcher the cab is located between the low hood covering the power plant equipment in front of the cab and a low hood, providing space for train steam heating boiler, in the back of the cab.

The section of the hood covering the engine-generator set is removable. The radiators and fan are mounted in a fixed portion of the hood at the front end of the locomotive while the control equipment is located in a fixed portion of the hood next to the cab. The hood is designed to provide maximum visibility and is equipped with hatches on the top and doors on the sides through which the engine and auxiliary equipment may be maintained. Louvers are also provided to give adequate engine room ventilation.

DIESEL ENGINE

The Diesel engine is a 6 cylinder "In-line" engine having a bore and stroke of 12-1/2" by 13", single acting and either turbocharged or non-turbocharged. It is of four stroke cycle having an open combustion chamber with solid fuel injection. An individual fuel injection pump and nozzle are provided for each cylinder.

The engine has a speed range of 275 to 740 RPM and is governed by a Woodward hydraulic governor.

Each cylinder requires two engine revolutions or four strokes of the piston to complete one working cycle. One complete piston working cycle is as follows:

On the first, or suction stroke, air is drawn into the cylinder, On the second, or compression stroke, this air is compressed by the rising piston to a pressure of about 450 pounds per square inch, which raises the temperature in the cylinder to about 1000 degrees F. Just before the end of the compression stroke, fuel is injected into the cylinder where it is ignited by the heat of the compressed air. The heat of the resulting combustion and the expansion of the gases furnish the power for the third, or working stroke. On the fourth, or exhaust stroke, the piston expels the gases from the cylinder and the cycle is complete.

The rate of injection of the fuel is so arranged that the maximum pressures do not exceed a safe working average. This assures a long life for all bearings and reciprocating parts.

The turbocharged engine functions in the same manner as described, except that air is blown in under pressure at the time the piston is traveling down on its "suction" stroke. This makes it possible for a larger quantity of air and fuel oil to be combined in the power stroke, thereby producing more power. This system of turbocharging holds the maximum pressures and temperatures down to normal conditions.

The two ends of the engine are known as GENERATOR

end and FREE end. The right hand side of the engine is determined by looking from the GENERATOR end toward the FREE end and is also known as the "A" side, whereas the left side of the engine is known as the "B" side. Cylinder numbering begins with 1 at the FREE end, runs consecutively down to the GENERATOR end.

LOCOMOTIVE OPERATION

Operation is simple. The engineer adjusts horsepower to meet load requirements by means of a throttle which sets the governor that regulates the flow of fuel to the engine. To reverse the direction of motion, the engineer closes the throttle, stops the locomotive, moves the controller handle to the opposite position, which reverses the traction motor fields and then opens the throttle. The braking system, sanders, bell, horn and other appurtenances are similar to those of any locomotive.

The electric method of transmitting power from the Diesel engine to the driving axles has several marked advantages. The electric drive in effect is a variable transmission, with an infinite number of ratios, that automatically adjusts itself to load conditions, thus, the Diesel engine can always operate in an efficient speed range and full engine horsepower is available for any load condition.

When starting a train, the traction generator supplies low voltage, high current power to the traction motors and the output of the Diesel engine appears at the driving wheels as high tractive effort at slow speeds. As the locomotive accelerates, the transfer of electric power is at a higher voltage and a lower current and the same engine horsepower is applied to the drivers as lower tractive effort at a higher speed.

Flexible cables connect the generator with the traction motors, thus, there is no rigid connection to transmit road shock to the engine. Power is transmitted smoothly which permits easy coupling and accurate spotting of cars.

TRACTION AND AUXILIARY GENERATORS

The traction generator is direct-connected to the engine crankshaft while the auxiliary generator and exciter, mounted on a common shaft, are belt driven from the traction generator stub shaft.

The traction generator produces direct current for the operation of the traction motors; the exciter furnishes excitation for the traction generator while the auxiliary generator furnishes current for battery charging and low voltage circuits for lighting, control, fuel pump and exciter field excitation.

TRACTION MOTORS

Four traction motors are used on each locomotive. Each motor is supported by axle suspension bearings and a spring nest on the truck bolster.

Shrunk onto the motor armature shaft is a pinion which meshes with a drive gear pressed onto the axle. The gear ratio between the pinion and drive gear is expressed in two figures such as 75/16. The first number indicates the number of teeth on the drive gear and the second number indicates the number of teeth on the pinion.

The traction motors are connected either in series or series-parallel depending upon the generator voltage. During acceleration the steps are:

No. 1 Series
No. 2 Series-Parallel
No. 3 Series-Parallel Shunt (Reduced Field)

The steps take place in reverse order when a train is decelerating with power on.

TRANSITION

Transition is the changing of traction motor connections which may be controlled automatically or manually by the engineer positioning the controller handle.

REVERSING LOCOMOTIVE

The forward and reverse movement of the locomotive is controlled by the positioning of the reverser which, when moved from forward to reverse position by controls at the engineer's position, changes the direction of the current through the traction motor field windings.

TRACTION MOTOR BLOWERS

A belt driven blower is provided for each pair of traction motors. The blowers are mounted on the locomotive floor and supply cooling air through ducts to the pair of traction motors on the front truck and to the pair of motors on the rear truck.

RADIATOR FAN

A radiator fan, which runs at engine speed, is located in the forward end compartment which cools both engine water and lubricating oil. It is belt driven from the engine through a drive shaft and right angle gear box.

RADIATORS

Engine water and lubricating oil are cooled by air cooled radiators. The radiators are the standard sectional type of all brazed construction, located on each side of the forward end of the hood. All of the radiator cores on the left or fireman's side are for cooling water. On the 660 HP locomotives, the rear three radiator cores on the right side are for lubricating oil while on the 1000 HP locomotives, the rear four cores are for lubricating oil. The remaining cores on the right side are for cooling water. The radiator fan draws air through the radiators exhausting the heated air upwards through the fan opening.

The radiators and fan opening are completely covered by shutters. The roof or fan opening shutter is controlled manually from the cab while the side or radiator shutters are controlled manually at the shutters. By positioning the various shutters, temperature is controlled.

CONTROLS IN THE CAB

Control Stand

The control stand, on which are mounted various gauges, handles and push button switches necessary for the operation of the locomotive, is located on the right side of the cab.

Throttle

Power supplied by the engine is regulated by the throttle handle on the control stand at the engineer's position. The initial movement of the throttle closes contacts to operate the main motor and field circuit contactors.

Controller — For M.U. Operation, See "Series-holding Switch"

A controller is used to select the motor combination and for controlling the direction of movement. This has an operating handle with three Forward, one Off and three Reverse positions. The handle is normally placed in either the full Forward or full Reverse position before opening the throttle so that the motor connections are then automatically changed from Series to Series-Parallel and to Field Shunting with the contactors operating at the proper locomotive speeds without any attention on the part of the engineer. The handle can be placed in the First Forward or Reverse position and thus maintain the Series motor position or it can be placed in the Second Forward or Reverse position and thus limit transition to Series-Parallel motor position.

Push Button Switches

Located at the side of the control stand is a series of push button switches used to control the fuel pump, engine starting, cab heater and lighting circuits.

The order of push button switches is:

- Engine Start - Cranks engine from the battery. Spring loaded.
- Control - Energizes control circuits.
- Fuel Pump - Starts fuel pump motor.
- Front Headlight Dim
- Front Headlight Bright - Dim switch has to be closed before bright light will light.
- Rear Headlight Dim
- Rear Headlight Bright - Dim switch has to be closed before bright light will light.
- Gauge Light
- Dome Light
- Engine Room Light
- Number Lights
- Marker Lights
- Cab Heater - Starts cab heater motor.

Battery Switch

The battery switch handle and extension is located in the lower right corner of the contactor compartment door. Push the handle in to connect the battery to the electric circuits so that the engine may be started and the electrical devices will operate. When pulled out, with the engine stopped, all electric apparatus on the locomotive is dead.

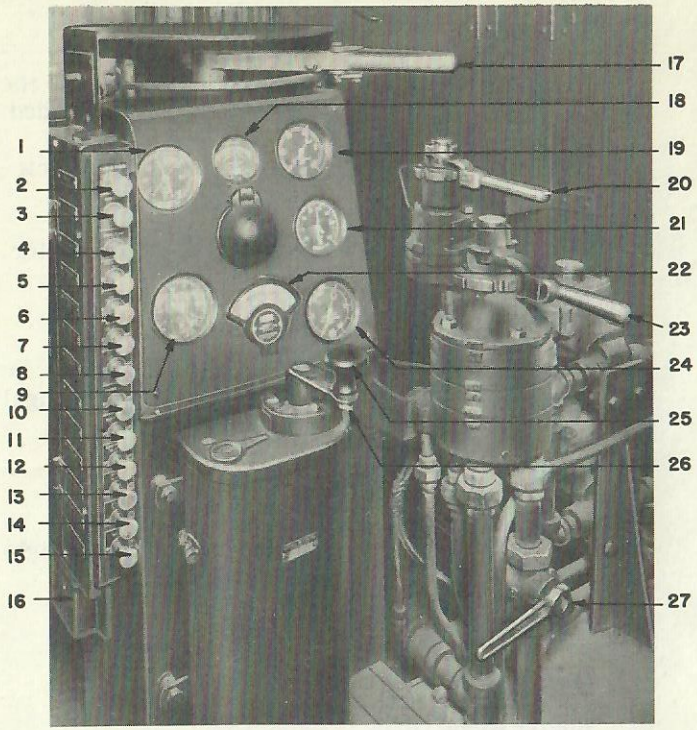


FIG. 1-0
ENGINEER'S POSITION - STANDARD SWITCHER

1. Main and Equalizing Reservoir Air Gauge

   Red - Main Reservoir Pressure
   White - Equalizing Reservoir Pressure

2. Engine Start Switch — cranks engine from the battery.

3. Control Switch — energizes control circuits.

4. Fuel Pump Switch — starts fuel oil pump motor.

5., 6., 7. and 8. Headlight Switches — for bright, first close dim switch and then bright switch.

9. Brake Cylinder and Brake Pipe Air Gauge

   Red - Cylinder Pressure
   White - Pipe Pressure

10.) 11.) Switches for Gauge and Dome Lights

12. Switch for Engine Room Lights

13.) 14.) Number Lights and Marker Lights Switches

15. Heater Switch — starts cab heater motor

16. Wheel Slip Buzzer — warns of wheel slipping

17. Throttle

18. Battery Charging Ammeter

19. Fuel Oil Pressure Gauge

20. Independent Brake Valve Handle

21. Control Air Pressure Gauge

22. Engine Water Temperature Indicator.

23. Automatic Brake Valve Handle.

24. Lubricating Oil Pressure Gauge

25. Controller Handle

26. Overload Indicating Light

27. Double Heading Cock

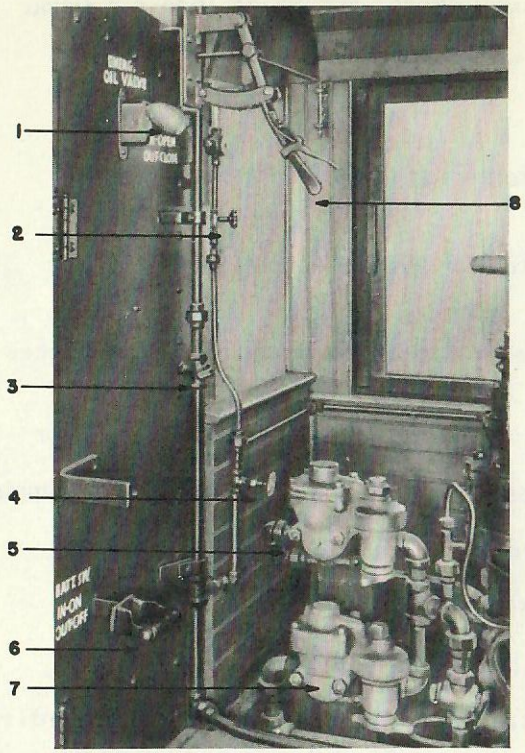


FIG. 2-0
ENGINEER'S POSITION - STANDARD SWITCHER

1. Emergency Fuel Oil Cutoff
2. Window Wiper Regulating Valve
3. Horn Cutout Cock
4. Window Wiper Cutout Valve
5. Feed Valve
6. Battery Switch Extension Handle —
   IN — Switch Closed
   OUT — Switch Open
7. Reducing Valve
8. Shutter Control — over radiator fan

AIR BRAKE EQUIPMENT NO. 14 EL

This equipment consists primarily of the automatic brake valve, independent brake valve, brake pipe cutout cock, feed valve, reducing valve and distributing valve.

The Automatic Brake Valve Handle has six positions, which are, beginning at the extreme left: Release, Running, Holding, Lap, Service and Emergency.

In the following paragraphs the positions are taken up in the order in which they are most generally used rather than in their regular order as mentioned above.

Release Position provides a large and direct passage from the main reservoir to the brake pipe to permit a rapid flow of air into the latter to (a) charge the train brake system; (b) quickly release; but (c) NOT release locomotive brakes, if they are applied.

If the handle were allowed to remain in this position, the brake system would be charged to main reservoir pressure. To avoid this, the handle must be moved to Running or Holding position. To prevent the engineer from forgetting this, a small port discharges feed valve pipe air to the atmosphere in Release position with sufficient noise to attract attention to the handle position.

Running Position is the proper position of the handle when the brakes are charged and ready for use; when the brakes are not being operated; and to release the locomotive brakes. In this position a large direct passage is opened from the feed valve pipe to the brake pipe, so that the latter will charge up as rapidly as the feed valve can supply the air, but cannot attain a pressure above that for which the feed valve is adjusted.

Service Position gives a gradual reduction of brake pipe pressure to cause a service application. The gradual reduction is to prevent quick action. The brake pipe discharge is also gradually stopped to prevent the pressure at the head end of the brake pipe being built up by the air flowing from the rear, which might cause some of the head brakes to "kick off".

Lap Position is used while holding the brakes applied after a service application until it is desired either to make a further brake pipe reduction or to release them.

Holding Position is so named because the locomotive brakes are held applied while the train brakes are being released and their auxiliary reservoirs recharged to feed valve pressure.

Emergency Position is used when the most prompt and heavy application of the brakes is required. A large and direct communication is made between the brake pipe and atmosphere. This direct passage makes a sudden and heavy discharge of brake pipe air.

The positions of the Independent Brake Valve Handle in order from the left are: Release, Running, Lap, Slow Application, Quick Application.

Release Position is used to release the locomotive brakes when the automatic brake valve handle is not in Running position. The independent portion of the brake valve is provided with a return spring which automatically moves the handle from Release to Running position as soon as the engineer releases his hold on it, the purpose being to prevent the handle from being left in Release position and thereby making it impossible to operate the locomotive brakes with the automatic brake valve handle. As a warning to the engineer in case of a broken return spring, air from the reducing valve is allowed to escape to the atmosphere in Release position. It also may be used to release locomotive brakes after an independent application at a faster rate than obtainable in Running position.

In Running Position communication is established through the distributing valve release pipe, between the application cylinder of the distributing valve and a port in the automatic portion of the brake valve so that the distributing valve can be released by the latter. It will also be noted that if the handle of the automatic portion is in Running position and the locomotive brakes are being operated, they can be released by simply returning the independent brake valve handle to Running position.

Lap Position is used to hold the independent brake applied after the desired cylinder pressure is obtained, at which time all communication between operating ports is closed.

In Slow Application Position, locomotive brakes are applied slowly.

Quick Application Position gives a quick application of locomotive brakes. The same spring that automatically returns the handle from Release to Running position also returns it from Quick Service to Slow Service position when the engineer releases his hold on it. The action of the spring between these two latter positions serves to make Quick Application position more prominent, so that in rapid movement of the handle the engineer is less likely to unintentionally pass over to Quick Application position, thereby obtaining a heavy application of the locomotive brakes when only a light one is desired.

The Brake Pipe Cutout Cock is located in the brake pipe underneath the brake valve and is used to open or close the passage between the brake valve and brake pipe. When the handle is vertical, the brake valve is cut out or closed; when the handle is parallel with the floor, it is cut in or open.

The Distributing Valve is the automatic valve mechanism which controls the operation of the brakes on the locomotive in accordance with the movements of the automatic and independent brake valve handles.

The M-3-A Feed Valve regulates the pressure in the brake pipe with the automatic brake valve in Running or Holding positions, and the M-3 reduces main reservoir pressure for use in independent brake operation and the train air signal system (if used). The M-3-A and M-3 feed valves are identical except that the M-3-A is provided with adjustable stops for double pressure control.

MISCELLANEOUS EQUIPMENT

Bell Valve

The locomotive bell is located under the chassis ahead of the battery box, right side. It is operated by main reservoir air pressure and controlled by a globe valve located on the cab side wall at the engineer's position. The clapper speed is regulated by a needle valve adjustment at the bell.

Horn Valve

The locomotive horn is operated by main reservoir air pressure through the control valve located at the engineer's position. A cutout valve, located in the cab, is provided in the air supply line.

Sander Valve

The sanders are operated by main reservoir air pressure and are controlled by a sander valve located to the right of the engineer on the cab side wall. The handle has three positions: Reverse, Neutral and Forward. Forward position admits main reservoir air to the sander automatic valve giving forward sanding, while the Reverse position admits main reservoir air to the sander automatic valve giving reverse sanding. A cutout valve, located in the cab, is provided in the air supply line.

Window Wiper Valves

Front and rear cab windows are equipped with air operated wipers. The speed of each wiper is controlled independently by a valve which also turns the wiper on and off. The operating valves are located at each wiper. A cutout valve, located in the cab, is provided in the main reservoir supply line.

Emergency Fuel Cutoff Valve

The emergency fuel cutoff valve, Fig. 3-0, furnishes a means of shutting off the flow of fuel from the tank to the Diesel engine in case of emergency. This valve is located in the suction line near the booster pump in the contactor compartment.

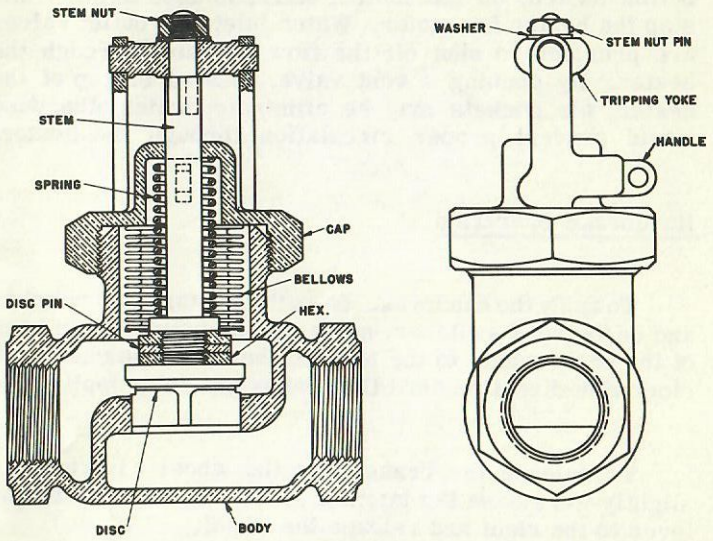


FIG. 3-0
EMERGENCY FUEL CUTOFF VALVE

It can be closed from three points on the locomotive by pulling the red knob at the engineer's position or at either side of the locomotive above the center of the rear truck.

When the valve is tripped (closed), the fuel pressure gauge should indicate zero pounds pressure. Reset manually by pulling up on the valve stem and reset the crutch which holds the valve open.

Cab Heater

The cab heater is located on the right side of the cab in front of the engineer's position. Hot water from the outlet header of the engine passes through the heater and a motor driven fan provides air circulation. A push button switch, on the control stand, is used to start and stop the heater fan motor. Water inlet and outlet valves are provided to shut off the flow of water through the heater. By opening a vent valve, located on top of the heater, air pockets may be eliminated which otherwise would prevent proper circulation through the heater.

Handbrake Operation

To apply the handbrake on both the standard switcher and on the road switcher, move the latching lever in back of the brake wheel to the left and then turn the wheel in a clockwise direction until the brakes are fully applied.

To release the brake, turn the wheel clockwise slightly to release the latching lever. Move the latching lever to the right and release the wheel.

GAUGES AND METERS

Battery Ammeter

The battery ammeter, located on the control stand, indicates the rate of battery charge and should show a charge of from 0 to plus 5 amps with the battery fully

charged. However, a much higher rate will be indicated immediately after the engine has been started.

Lubricating Oil Pressure Gauge

The lubricating oil pressure gauge, located on the control stand, should indicate 35-45 psi under normal operating conditions. The minimum pressure is 26 psi with the engine shutting down at 23 psi.

Fuel Oil Pressure Gauge

The fuel oil pressure gauge, located on the control stand, should indicate 35-40 psi.

Water Level Sight Glass

The water level sight glass, located on the engine water expansion tank, should always show water.

Control Air Pressure Gauge

The control air pressure gauge, located on the control stand shows the air pressure available for operating the reverser and the motor contactors. When pressure is too low, these air devices cannot operate, and the locomotive will not move under its own power. The gauge should show 70 psi when air system is charged.

Air Brake Pressure Gauges

The air brake pressure gauges, located on the control stand, should read in accordance with railroad practice. On the upper gauge the red hand shows main-reservoir pressure, while the white hand shows equalizing reservoir pressure. On the lower gauge the red hand shows brake-cylinder pressure and the white hand shows brake-pipe pressure.

Loadmeter

Road switcher locomotives are equipped with a loadmeter which is used as a guide for the operation of the throttle. By careful observance of this meter the engineer may get the maximum performance from the locomotive and guard against abusive overloading of the traction motors. Two types of meters are in use. One is designed with the outer scale divided into three colored zones, the other is divided into two colored zones with the last zone marked off in minutes.

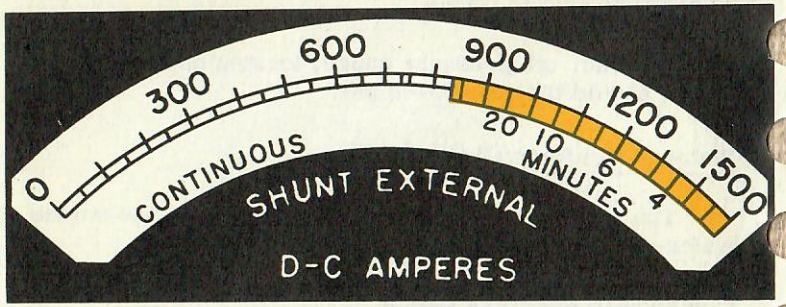


FIG. 4-0
LOADMETER

On one type, Fig. 4-0, the scale is white from 0 to 830 amperes which is the continuous rating of the traction motors. From 830 to 1500 amperes the scale is yellow indicating limited time operation. The yellow figures beneath this portion of the scale indicates the time in MINUTES these loads may be maintained. The operating time in this zone is not accumulative. When the locomotive has been operated at any of the overloads for the full time shown, or a combination of the overloads (for example, part time at the 10 minute and part time at the 20 minute rating) the load must be reduced into the white zone, 830 amperes or less, for one hour before repeating an overload.

The scale is also marked from 730 amperes up to 1500 amperes SERIES ONLY indicating that when operation requires load currents in this range, the locomotive should be operated in the series motor connection.

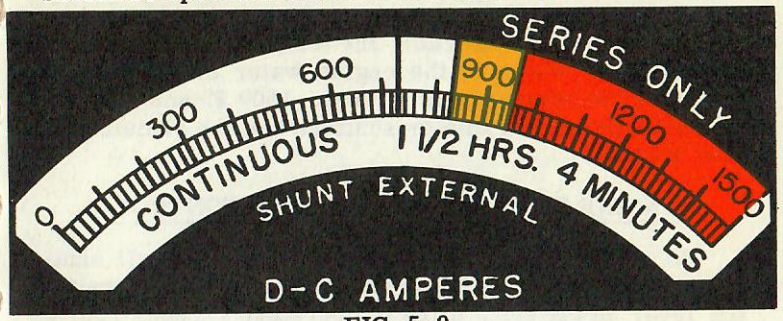


FIG. 5-0
LOADMETER

On the other type, Fig. 5-0, the scale is white from 0 to 830 amperes which is the continuous rating of the traction motors. From 830 to 950 amperes the scale is yellow indicating limited time operation. Operation in this zone is permissible for a consecutively or accumulative time not to exceed 90 minutes. From 950 to 1500 amperes the scale is red also indicating limited time operation. Operation in this zone is normally used for starting and accelerating a train. A train of proper tonnage should not require more than approximately 4 minutes operation in this zone.

The scale is also marked from 730 amperes up to 1500 amperes SERIES ONLY indicating that when operation requires load currents in this range, the locomotive should be operated in the series motor connection.

Wheel Slip Warning by Loadmeter

Normally wheel slip warning is given by the wheel slip relay system. The loadmeter may also be the engineer's warning of a wheel slip. Any sudden drop of loadmeter reading, not caused by a throttle reduction, is an indication of wheel slip.

Engine Water Temperature Gauge

The engine water temperature gauge, located on the control stand, indicates the temperature of the engine cooling water in the engine water outlet header. Maintain the temperature between 150° F and 170° F by manipulating the radiator shutters and the radiator fan roof shutter.

ENGINE WATER TEMPERATURE CONTROL

In controlling temperatures, start out with all shutters closed. Then first open the roof shutter by operating the lever in the cab. If the temperature exceeds 160° F with the roof shutters wide open, the side shutters should be opened beginning with the right, or engineer's side, in the summer time, and beginning with the left, or fireman's side, in the winter time. This arrangement gives better oil cooling since oil and water cores are mounted on the right side, while only water cores are mounted on the left side.

If the water temperature exceeds 180° F, determine the cause.

NEVER LET THE TEMPERATURE EXCEED 190° F.

ALARMS

Generator Overload Indicating Lamp

When the current in traction motors No. 3 and No. 4 reaches the safe limit for the main generator, overload relay CL closes and lights an indicating lamp on the control stand. This relay operates only when the locomotive is in series-parallel.

When the lamp lights (disregard flickering), either close the throttle and then reopen it (this operation places the traction motors in series) or reduce the throttle position to not more than 1/4 open and return the controller handle to series position.

Wheel Slip Buzzer

When wheels on No. 1 or No. 2 traction motors slip, WS1 relay closes and when wheels on No. 3 or No. 4 traction motors slip, WS2 relay closes. Either relay operates the wheel slip buzzer on the control stand and removes power from the main generator, thereby automatically stopping wheel slippage. When this occurs, ease off the throttle only when slipping is recurrent. The practice of using sand to overcome wheel slipping without first reducing the throttle position is definitely contrary to our recommendations. The proper use of sand will minimize wheel slippage. Use sand to prevent but not overcome wheel slippage.

Some locomotives do not have the power-removal feature. In this case, when slipping occurs, shut off or partially close the throttle until the buzzing stops; this indicates that slipping is over.

SAFETY DEVICES

Lubricating Oil Low Pressure Switch

The engine is protected from low lubricating oil pressure by means of oil pressure switch No. 115 and governor solenoid No. 113.

The oil pressure switch is held closed by the lubricating oil pressure and when this switch is closed, current flows from the switch to the governor solenoid. The governor solenoid, when energized, closes a pressure relief valve inside the governor and allows the governor to build up the internal pressure necessary for proper functioning.

If the Diesel engine lubricating oil pressure should fail, the oil pressure switch will open breaking the electrical circuit to the governor solenoid. The solenoid will then become de-energized, open the pressure relief valve in the governor and the governor will then bring the fuel pump racks to shutoff position.

The oil pressure switch is set to close at 23 psi and open at 20 psi. Therefore, in starting the Diesel engine, the starting button has to be held in until the lubricating oil pressure as indicated on the pressure gauge is above 23 psi. If the starting button is released before this pressure is reached, the Diesel engine will shut down.

Ground Relay

Automatic indication of a ground in the electrical apparatus is provided by means of a ground relay, GR, in the generator circuit.

When a ground occurs and the ground relay operates, the exciter field contactor, EF, opens, disconnecting the exciter field from the battery to greatly decrease the main generator voltage. The generator field contactor, GF, also opens, reducing the main generator voltage still further by the insertion of the GFR resistor in the shunt field of the main generator.

To reset the ground relay:

1. Close throttle to Idle position.
2. Reset relay by raising the holding latch. The GR relay can be reset by hand only. It is located in the contactor compartment of the locomotive.
3. If a ground persists, open ground relay cutout switch 108, reset the relay and move the locomotive no farther than necessary to get into the clear.

Engine Overspeed Trip

The engine is equipped with an overspeed automatic stopping device which has been set in the factory on the test stand at approximately 850 RPM. This stopping device consists of two spring-loaded weights which, under normal operation, are against their inner stop. These weights do not move until the centrifugal force has become great enough to overcome the spring force,

and when this point has been reached the weights move out instantaneously to their outer stop.

These weights in their outer position hit a trigger and release the cutout shaft which shifts endwise and allows the cutout plungers, which are spring-loaded, to engage the fuel pump crosshead guides and thus make the fuel pumps inoperative by holding the crossheads and rollers off the fuel pump camshaft.

To reset, pull out each Bosch pump cutout plunger and turn until the trip pin points straight down. Pull out on the reset handle until it latches and then pull out and turn each plunger to engage trip pin in the notch in the rack.

During maintenance work, when the engine is not in operation and the safety device is tripped, it will sometimes be necessary to pull out all the cutout knobs and free them from the rack by turning them until the trip pin is pointing straight down, before the rack can be reset. This is due to some of the plungers not engaging with the pump crossheads which are not standing at top center.

The safety device weight assembly is built as a separate assembly and mounted between the fuel pump camshaft and governor drive gear. If for any reason this safety device weight assembly has been removed after reassembling make sure weights can be moved by hand; this can be done by pulling on both weights. If everything has been properly reassembled the weights will easily move back and forth. If they do not, then it will be necessary to recheck the assembly and relieve any binding.

Check the device periodically with an engine tachometer to make certain the setting is correct.

OPERATION - STANDARD SWITCHERS

PREPARING FOR OPERATION

1. If lights are needed, close battery switch and close the necessary push button switches.
2. Inspect engine compartment to see that no rags, tools, lanterns, etc. are near shafts, belts, or other moving parts or electrical apparatus. Waste should never be used on the locomotive.
3. Check level of engine lubricating oil. Bayonet gauge should show oil between high and low marks.
4. Check fuel oil level.
5. Check cooling water level. The sight glass attached to the expansion tank should show water at all times.
6. Check oil level in engine governor. The oil level in the sight glass should be maintained as closely as possible at the middle point. Oil should be added whenever the oil drops below the bottom of the sight glass.
7. Check sand supply. There are two tanks at the front end and one tank at the rear end, all three being filled through roof filling holes.
8. The emergency fuel shutoff valve should be open. If closed, reset by raising the valve stem and slipping the crutch under the raised stem.
9. Make sure the cooling water drain valves are closed.
10. Make sure the lubricating oil drain valve is closed and the cap on the external drain pipe is securely tightened.

11. The handle on the duplex fuel oil filter should be either in the horizontal or vertical position. In the horizontal position, the filter farthest from the handle is cut in. In the vertical position, both filters are being used.
12. The air compressor governor cutout valve must be open.
13. The throttle must be in Idle and the controller in Off position.
14. Check engine overspeed trip for proper setting.
15. Check air compressor oil level. Maintain the oil level at the full mark on the bayonet gauge with the engine shut down.
16. Check water level in steam generator water tank, if used.
17. Give handles in fuel and lubricating oil line filters one turn.

STARTING DIESEL ENGINE.

1. Close Battery Switch 100 (Fuse 105) (110 Amp).

   This switch must be closed and the fuse good for engine to run. When open, this switch disconnects all relays, contactors and lights from the battery and thus de-energizes all apparatus on the locomotive.

2. Move Throttle To Idle Position

   The throttle controls the speed of the Diesel engine as well as the closing of the main traction-motor contactors. When starting a Diesel engine, it should be in the Idle position so that the Diesel engine, after it fires, will be held to idling speed.

3. Turn Controller Handle To Off Position

The Diesel engine cannot be started unless the controller is in Off position. In this position the traction motor contactors cannot be closed, therefore, the locomotive cannot move under its own power.

4. Close Fuel Pump Switch

This starts the fuel pump motor, provided that the main battery fuse 105 (110 amp) and fuel pump switch fuse (10 amp) are good.

The fuel pump draws oil from the fuel tank under the cab floor through filters to the fuel oil header at the high pressure pumps on the side of the Diesel engine.

The fuel pump switch puts voltage on one side of governor solenoid coil 113 so that it will operate when the engine starting contactors close.

5. Wait For Fuel Oil Pressure To Build Up

This pressure should be about 40 psi. The fuel oil is forced under pressure to the header on the side of the Diesel engine where the high pressure pumps can pick it up and pump it to the Diesel engine injection nozzles.

6. Close Control Switch

Although the control push button switch must be closed and its fuse must be good in order to start the engine, it does not have to be closed to allow the engine to idle or to run above idling speed. If it is open, however, contactor B will be cut out and the auxiliary generator cannot charge the battery.

This control switch controls the following:

Battery charging contactor B
Wheel slip buzzer
Overload indicating lamp
Starting contactors GS1, GS2
All traction relays and contactors

A 10 amp fuse at each push button switch must be good in order to make its respective circuits operative.

7. Close And Hold In Engine Start Switch

Provided the 10 amp fuse in this push button switch is good, engine starting contactors GS1 and GS2 will close if the following interlocks are in the position shown:

Interlock contacts, 51-51A on controller closed with controller Off.

EF interlock contacts, 51A-51B closed with EF contactor open.

B interlock contacts, 51B-51C closed with B contactor open.

The above interlock 51-51A on the controller makes it impossible to close GS1 and GS2 engine starting contactors unless the controller is in Off position. Therefore, the locomotive cannot move under its own power when the Diesel engine starts.

The EF interlock makes it impossible to connect the main generator to the battery through GS1 and GS2 contactors while the generator is operating as a generator. If it were not for this interlock, the main generator with a normal voltage of 600 volts could be directly connected to the battery with a normal voltage of 64 volts with disastrous results.

The B interlock makes it impossible to close GS1 and GS2 starting contactors while the Diesel engine is running and the belt-driven auxiliary generator is charging the battery. This prevents damage by the unintentional or accidental closing of the engine start switch which would connect the main generator across the battery.

In addition, the control circuits are protected by the action of the RC relay and its contacts.

The closing of GS1 and GS2 contactors connects the battery to the main generator armature through a special starting field on the generator.

Governor solenoid pulls down

After the fuel pump switch is closed, the governor solenoid (113) is energized when the GS1 interlock contacts 52B-65 are closed. The governor solenoid interlock 113 short circuits the resistor 114, which permits the governor solenoid to operate. As the solenoid armature moves downward, the interlock opens and the resistor limits the current to a value that will hold the solenoid armature down without burning out its coil. If the interlock contacts do not short circuit the resistor, the current will be too weak to pull the solenoid down. The governor solenoid armature operates the governor dump valve which closes the power piston by-pass.

Diesel engine turns over

The generator, acting as a series motor, will, provided the battery is in good condition, turn the Diesel engine over at a speed high enough to compress the air and fire the fuel oil charge in each cylinder.

Governor power piston rises

While the Diesel engine is being cranked, the governor pump is building up oil pressure to operate the power piston because the by-pass or dump valve around the power piston has been closed by the governor solenoid. When the pressure builds up, the power piston rises and through a combination of levers operates each fuel injection pump control rod.

Diesel engine fires

With the engine turning over and with its high pressure constant stroke pumps being moved up and down by cams on a common camshaft, the movement of the control rods by the governor will allow fuel oil to be pumped from the fuel oil header on the side of the engine, up through a delivery valve at the top of each pump unit and thence to the nozzle in the top of each cylinder. If the air in each cylinder has risen to a high enough temperature, due to its compression by the piston, the finely atomized fuel oil will burn when it enters the top of the cylinder and cause the engine to "fire" and deliver power.

Compressor starts to pump air

The air compressor is directly connected to the Diesel engine and has no electric connections in its control. When the engine starts, the compressor starts to pump air for the locomotive air-braking system and for the control apparatus. The air pressure in the main reservoir is determined by the setting of the air compressor governor which unloads the compressor after it has built up to the main reservoir setting. Control air pressure at 70 psi is obtained from the main reservoir through a reducing valve which feeds into a control air reservoir.

8. Wait For Lubricating Oil Pressure To Build Up

After the engine fires it is necessary to hold the engine start switch closed until the lubricating oil pressure rises to about 25-30 psi. While it is held in an interlock on GS1 contactor holds the governor solenoid down. If the engine start switch

is released before the lubricating oil pressure rises to the closing point of oil pressure switch 115, the governor solenoid will be released and the engine will stop firing for lack of fuel.

Engine lubricating oil pressure switch 115 closes.

The oil pressure switch has its contacts in parallel with interlock 52B-65 on GS1; therefore, it is necessary to wait until this switch closes.

9. Release Engine Start Switch

After oil pressure has built up with the Diesel engine running, the engine start switch may be released without releasing the governor solenoid. Engine starting contactors GS1 and GS2 open.

Voltage regulating relay X holds steady voltage.

The auxiliary generator is used for battery charging. The auxiliary generator field is connected to the battery through the RC series coil, the B interlock and the contacts of the voltage regulating relay. Before the engine turned over there was no voltage across the fixed and floating coils of this relay. All of the relay contacts are held closed by springs and the current in the field of the auxiliary generator is at its maximum value. The auxiliary generator is belt driven by the Diesel engine. As the engine starts running the auxiliary generator armature also begins to rotate and build up voltage. As this voltage increases more current passes through the voltage regulating relay coils which tend to pull open the contacts of this relay to decrease the auxiliary generator field current and, consequently, the voltage of the auxiliary generator itself. No actual movement takes place until the voltage reaches approximately 74 volts. At this voltage the relay contacts move to a position which will maintain this voltage. Thereafter, the contacts float in

about the same position to hold a steady auxiliary generator load. When the auxiliary generator speed increases with the increase in speed of the Diesel engine, the voltage-regulating relay contacts will automatically assume new positions, inserting more resistance in series with the auxiliary generator field to hold the same 74 volts output available for charging the battery. This relay has other resistors connected in such a way as to prevent hunting and overshooting of voltage. The floating coil has a small section which compensates for varying pressure of the stationary contact finger springs as the movable bar closes more or fewer fingers. This coil also minimizes any difference in voltage between high and low engine speeds.

Reverse current relay RC closes

If the 80 amp. auxiliary generator fuse 103 is good, the voltage at the auxiliary generator terminals will be applied to the shunt coil of reverse current relay RC. Current in this shunt coil tends to pick up the relay and close its contacts. However, while the auxiliary generator is coming up in speed with a voltage lower than the battery (64 volts nominally), current also flows through the differential coil of RC relay from the battery to the auxiliary generator. This tends to prevent the relay from closing its contacts. When the voltage of the auxiliary generator rises so that it is above battery voltage, current in the differential coil of RC relay will reverse and neutralize the magnetic flux in the differential coil core. This allows the flux in the shunt coil core to operate the relay and close its contacts. When RC contacts close, battery charging contactor B closes, provided GS2 contactor is open and has its 50C-50D interlock closed. Current then flows from the auxiliary generator to the battery. These 50C-50D interlock contacts on GS2 prevent the auxiliary generator from being connected to the battery while the battery is cranking the engine.

Reverse current relay RC has three coils and three separate magnetic cores as shown below:

Upper coil and core - shunt
Center coil and core - series
Lower coil and core - differential

It must be remembered that it is not the current through a coil which determines the operation of a relay – it is the magnetic flux produced by that current which does the work.

In a three-legged relay, like this RC relay, the flux produced by the current in a coil on one leg has a choice of two paths, through either of the other two legs, by which it can complete its magnetic circuit.

The interchange of flux between these three legs produces a condition which should snap the relay from one extreme position to the other eliminating any tendency to pump in and out.

Battery charging contactor B closes. Battery charging starts.

After B contactor closes, current flows in the series coil of RC relay to assist in holding its contacts closed while current is flowing from the auxiliary generator to the battery. Interlock 4-4A on B contactor opens to insert resistance in the shunt pick up coil of RC relay to raise its drop out point to allow it to open at the proper time. When the auxiliary generator voltage drops so low that current will flow from the battery to the auxiliary generator, the current in the RC series coil reverses and neutralizes the flux in both the shunt core and the series core. The relay pull out spring then opens the contacts and lets the armature swing back to touch the differential coil core. It remains there until the auxiliary generator voltage again rises

above battery voltage. When RC relay opens, B contactor opens and the auxiliary generator is disconnected from the battery.

FASTER AIR PUMPING

1. Start Engine

2. Make Sure Controller Handle Is In Off Position

In this position the locomotive cannot be moved under its own power since power is prevented from reaching the traction motors. The controller in its Off position holds open the control circuits to the reverser operating magnet valves, to the exciter and generator field contactors EF and GF and to all traction motor contactors.

3. Open Throttle

Air pressure can be built up faster by opening the throttle somewhat less than half way. Running the unloaded engine with the throttle open wider is bad practice. Close throttle when air is up.

MOVING THE LOCOMOTIVE

1. Start The Diesel Engine

2. Wait For Main Air Reservoir To Build Up To Operating Pressure

No pneumatically operated contactors are used for starting and running an engine above idling speed, so air pressure is not necessary. The heavy contacts on the reverser and the traction motor contactors carry the full traction-motor current. High contact pressure is necessary to carry these heavy currents. Therefore, the Reverser and the S, SP1, and SP2 contactors are operated by air pistons in cylinders at 70 psi. air pressure. Air is admitted

to the operating cylinders by magnet valves whose operating coils are electrically interlocked so that they will operate at the correct time.

Before moving the locomotive, it is also essential that sufficient air pressure be available for operating the air brakes.

3. Test Air Brake Operation

Before applying power to move the locomotive it is essential to know if the locomotive brakes can be applied and released by manipulating the brake valves, otherwise the locomotive might be moved and then be out of control. Make a test application and brake release.

4. Turn Controller Handle To Position Desired

Manual Transition

The controller has seven positions: Series, Series-parallel and Reduced-Field for each direction of movement and Off. Limitation to Series-parallel or to Series connections of traction motors may be made by keeping the controller handle in the desired position.

Series - low speeds

If the traction motors are to be operated only in Series, the controller handle should be turned to a Series position. Then, regardless of locomotive speed, this Series connection will be maintained as long as the throttle closes the throttle switch.

Limitation to Series is very useful in ascending a grade that has dips in it which, if this limitation were not used, would allow a locomotive speed high enough to transfer to Series-parallel and then would require a manual transfer back to Series at the end

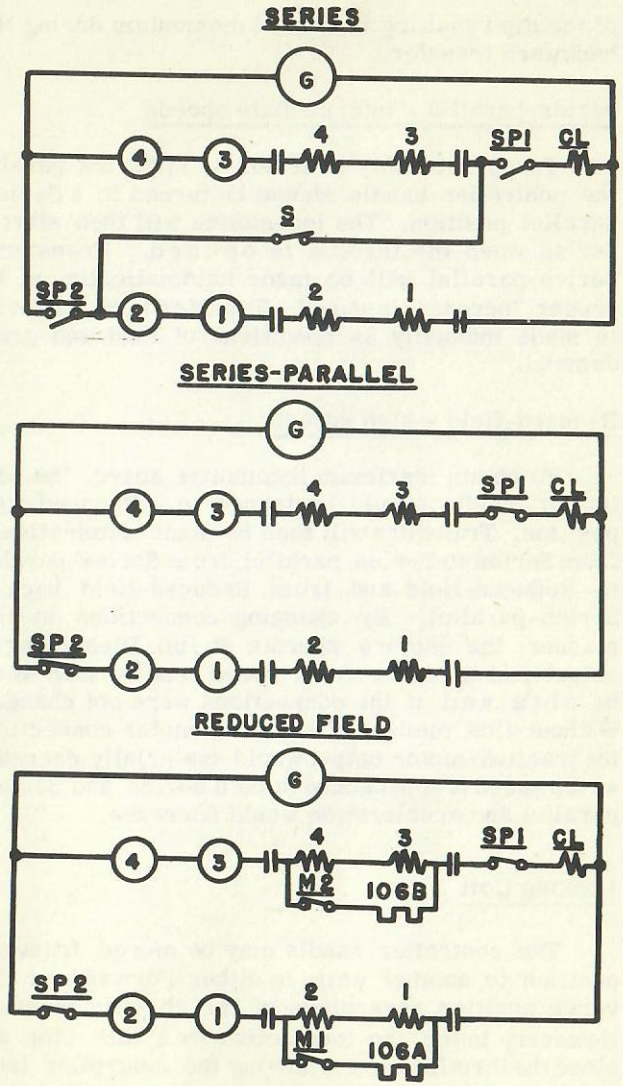


FIG. 3-0
SCHEMATIC DIAGRAM OF TRACTION-MOTOR CONNECTION

of the dip resulting in loss of momentum during this backward transfer.

Series-parallel - intermediate speeds

To operate only in Series or in Series-parallel the controller handle should be turned to a Series-parallel position. The locomotive will then start in Series when the throttle is opened. Transfer to Series-parallel will be made automatically at the proper increase in speed. Transfer back to Series is made manually as conditions of load and grade demand.

Reduced-field - high speeds

To obtain maximum locomotive speed, the controller handle should be turned to a Reduced-field position. Transfers will then be made automatically from Series to Series-parallel, from Series-parallel to Reduced-field and from Reduced-field back to Series-parallel. By changing connections in this manner, the motors operate at full Diesel-engine output and a higher train speed results than would be obtained if the connections were not changed. Without this method of changing motor connections the traction-motor output would materially decrease as top speed is approached in both Series and Series-parallel and acceleration would decrease.

Locking Coil

The controller handle may be moved from one position to another while in either Forward or Reverse position regardless of the throttle position. However, bring the locomotive to a full stop and close the throttle before moving the controller from Forward to Reverse or vise versa as a locking coil will lock the controller in Off position with the throttle open. To unlock the coil, close the throttle.

Automatic Transition

The controller handle should be moved to reduced field position to utilize the automatic transition feature.

With the controller in this position the traction motors operate in Series up to 8 MPH, then they are automatically connected in Series-parallel. At 23 MPH they are automatically reconnected for reduced field. The transfer back to Series-parallel is also automatic at 16 MPH (at full throttle) but the transfer from Series-parallel to Series must be made manually when the CL indicating lamp lights, which is approximately 6.5 MPH on the 660 HP locomotive and 7.7 MPH on the 1000 HP locomotive, either by closing the throttle and reopening or by reducing the throttle to 1/4 opening and turning the controller handle to Series position.

If the locomotive is equipped with a loadmeter, see that currents above 730 amps are for Series operation only.

5. Release Brakes (hand brakes as well as air brakes)

Unlike a steam locomotive serious damage can be done to the traction motors on a Diesel-electric locomotive when power is applied with brakes set. In a steam locomotive when steam enters a driving cylinder it builds up pressure against the piston. If air brake pressure on the drivers prevents the piston from moving, pressure is held against this piston and no harm is done.

In a Diesel-electric locomotive, when power is applied to the traction motors, current flows from the main generator through cables to carbon brushes in each motor. Passing through the brushes, this current goes through only a few commutator bars, (less than 10 per cent of the total number of bars)

and thence through the armature coils where it develops torque to rotate the motor shaft. The purpose of the commutator bars is to allow current from the stationary brushes to enter the armature coils at the proper place during rotation to develop the most torque.

If the load is too heavy or the locomotive brakes are applied sufficiently (or both) to prevent the wheels from turning, all of the generator current will pass through the same motor commutator bars and will greatly overheat them. All of the other bars will remain comparatively cool. This localized heating of less than 10 per cent of the commutator bars may cause annealing of those particular bars, or may expand them sufficiently to raise their outer surface above the normal commutator surface. It may even melt the solder which joins the ends of the armature coils to these bars.

If the brakes are released enough to allow the motors to turn, even though slowly, the commutator bars passing under the current-carrying brushes will carry the high current for less than 10 per cent of the time and the commutator, even though it carries an abnormally high current, would heat evenly without any harm being done, provided this abnormally high current does not last for more than a very short time (less than 4 minutes).

6. Water Temperature

Have at least 110° F to 120° F water temperature (if possible) before putting locomotive to work. This can be accomplished either through the use of low pressure house steam or by opening the throttle slightly to allow the engine to run above idling speed with all shutters tightly closed.

7. Open Throttle

When the throttle is first opened the control circuits are energized, the generator is connected to the traction motors and the locomotive starts to move.

Successive advancement of the throttle acts on the governor to admit more fuel to the engine. The engine speed will increase until it reaches the setting of the governor as controlled by the throttle. More power is delivered to the generator and thus to the traction motors.

When moving cars open the throttle just out of the idling position and wait for the slack to be taken up; then open the throttle steadily as rapidly as desired up to the slipping point of the wheels. Throttle movements should be smooth and continuous; do not jerk the throttle on and off. When the locomotive has accelerated to the desired speed, ease back on the throttle to the point where the speed is maintained. If locomotive at full throttle does not readily accelerate train to more than 6-1/2 MPH, reduce train weight.

With engine running and controller handle in an operating position, never leave the throttle open if the locomotive is not moving as this can seriously damage the traction motors.

OPERATING IN SERIES - LOW SPEEDS:

With the control switch closed and its fuse good, turn controller handle to its Series position Forward.

Open throttle - throttle switch 101 will close.

The controller locking coil will then be energized to prevent the controller handle from being turned into any Reverse position until after the throttle has been closed.

If the controller handle is turned to its Off position with the throttle open, the controller handle cannot be turned out of Off position even into its former position until the throttle is closed to its Idle position which opens the throttle control switch.

The closing of throttle switch 101 when the throttle is opened will also, through contacts 1 and 8 on the controller, energize the Forward magnet valve on the reverser, which will admit air at 70 psi pressure to the reverser air engine and turn it into its Forward position or hold it there if it is already in that position.

With the reverser in its Forward position its Forward interlock will close and complete a circuit to pick up the following contactors through the Forward segment of the controller:

EF contactors, provided WS1 and WS2 relays are open and have their contacts 8A-8K and 8K-8L closed and GR relay is open and has its 8L-8H interlock closed.

S contactor, provided SP1 contactor is open and has its 8A-8B contacts closed.

The purpose of having reverser interlocks control the excitation contactors EF and GF is to make sure that the reverser is in a running position before any current flows and that its position is the same as that selected by the controller handle. This minimizes the burning of the reverser contact segments and fingers and assures movement only in the direction desired. These reverser interlocks are 8-8A for Forward movement and 0-8A for Reverse movement.

EF contactor's main contacts 60-R8 will connect the exciter shunt field to the battery through resistors R6-R7 and R7-R8. Resistor R7-R8 reduces the exciter voltage so that "soft" starting and easy spotting of the locomotive can be obtained.

Throttle switch 110 will close and short circuit resistor R7-R8 with the throttle opened. This will restore the higher normal excitation.

The S contactor will connect the four traction motors in series across the main generator.

Then GF contactor will close, connecting the main generator field directly to the exciter. This will give full main generator voltage to move the locomotive in Series.

OPERATING IN SERIES-PARALLEL - MEDIUM SPEEDS

With the locomotive moving in Series, turn the controller handle to Series-parallel, Forward. This will connect battery positive to controller contact 2 which will allow the Series to Series-parallel contacts 2-2A on transition relay V to be effective when relay V picks up.

As the locomotive increases in speed, the motor current and, consequently, the generator current, decreases, while the generator voltage simultaneously increases. When the ratio of voltage pull-in effect to the current holdout effect increases to the operating point of the relay, this relay will close both its contacts, 3-3A and 2-2A. Contacts 3-3A will be ineffective because they have in series with them the open interlock contacts 3A-3B on contactor SP2. Also, they will not be connected to the battery until the controller handle is turned to its Reduced-field position.

The 2-2A contacts of relay V will close relay CR1. This relay holds itself in through its own 2-2A contacts which are closed when the relay is closed. The 2-2A contacts of relays V and CR1 are in parallel.

When CR1 relay closes, its 8C-8D contacts will open and, in turn, open generator field contactor GF. The main contacts GS-EA of contactor GF opening will insert

resistance in the field of the main generator. This decreases the main generator voltage in preparation for the transition operations to follow.

When contactor GF opens, its interlock 2A-2B will close traction motor contactor SP1 which will hold itself in through its own 2A-2B interlock. This interlock is in parallel with a similarly numbered interlock on contactor GF.

When contactor SP1 closes, No. 1 and No. 2 traction motors will be short circuited through SP1 main contacts. No harm will be done, however, because an instant previously the current in these motors has been reduced and the voltage across them decreased by the opening of the main contacts of GF. The closing of SP1 main contacts also will connect No. 3 and No. 4 traction motors directly across the generator.

As soon as SP1 closes, its 8A-8B interlock contacts will open and drop out contactor S, which will remove the short circuit on traction motors No. 1 and No. 2. The dropping out of contactor S will allow its 2B-2C interlock to close contactor SP2, which will connect traction motors No. 1 and No. 2 directly across the generator. The 2C-8D interlock on contactor SP2 will also close and, in turn, close contactor GF whose main contacts GS-EA will put full exciter voltage on the main generator field and rebuild the main generator voltage up to normal.

When operating in Series, the full current from the main generator passes through each traction motor in succession, from positive of main generator, through No. 4 traction motor to No. 3 motor, through the main contacts of Series contactor S, to No. 2 motor, to No. 1 motor, and back to main generator negative.

The characteristic of the main generator is such that it holds approximately constant horsepower on the Diesel engine. However, since the output of the generator is the product of its voltage times its current, a constant

output requires only a constant product of volts and amperes. It makes no difference if the volts are high and the amperes are low or if the volts are low and the amperes are high, just so long as the product of the two remains the same. This output characteristic of the main generator is determined by the split pole exciter.

When starting the locomotive from standstill, a very high current can be taken by the traction motors. This can easily damage the traction motors if the motors cannot move because either the brakes are set or the train is too heavy. If the traction motors can rotate, they automatically, by their inherent characteristics, increase the voltage and decrease this current so that, as the locomotive accelerates, the generator current decreases and its voltage increases. When this voltage reaches the top voltage for which the generator was designed, a change in motor connections is made by the operation of transition relay V. This change of traction motor connections is from Series, with all of the main generator current passing through all traction motors, one after the other, to Series-parallel in which the current from the main generator splits, half going through No. 2 and No. 1 motors, one after the other, and the other half going through No. 4 and No. 3 traction motors, one after the other. With the horsepower or the product of the generator volts and amperes remaining constant, this transfer from Series to Series-parallel results in a change in the generator from a condition of high voltage and low current to a condition of low voltage and high current, the horsepower load on the Diesel engine being the same.

During this change of connections, transition relay V opens, not only because of the drop in generator voltage, but also because of resistance being inserted in its voltage pickup coil by the opening of the 5A-5B interlock on contactor GF while GF is open. When GF closes again after the transition is complete, transition relay V is again in its normal condition, ready to close its contacts whenever the combination of high generator voltage and low generator current occurs again.

OPERATING IN SERIES-PARALLEL – REDUCED-FIELD – HIGH SPEEDS

With the locomotive moving in Series-parallel, turn the controller handle to Reduced field. This will connect battery positive to controller contact 3, which will allow the contacts 3-3A on transition relay V to be effective when relay V closes. This relay maintains full load on the Diesel engine by changing the traction motor connections.

When the relation between train weight and grade and track conditions permits operation at locomotive speeds above approximately 23 mph, the engine horsepower is more effectively utilized by changing the traction motor field connections, which is done automatically by the relay V, provided the controller handle is in the Reduced field position. With the traction motors connected in the Series-parallel connection, as the locomotive continues to accelerate at a speed of about 23 MPH, the voltage will again reach the top voltage for which the generator was designed, with a simultaneous decrease in current which will cause relay V to close again. Now, contacts 2-2A are ineffective as they are paralleled by the 2-2A closed contacts of CR1 relay. When contacts 3-3A on V relay close, they will close Reduced field contactors M1 and M2. Each of these contactors has a resistor in series with its main contacts. When M1 contactor closes, resistor 106A will be connected in parallel with the fields of No. 2 and No. 1 traction motors. When M2 contactor closes, resistor 106B will be connected in parallel with the fields of No. 4 and No. 3 traction motors. Hence, part of the current in the motor armatures will be diverted through these resistors, with a resulting decrease in current through the motor field coils. When the field strength of any motor is decreased, its armature tries to increase in speed to compensate for this. The weakening of the fields allows more current to flow through the motor armatures; thus, more current is taken from the main generator. To maintain constant horsepower, the generator voltage drops, thereby maintaining the same product of volts and amperes.

When M1 contactor closes, its 5-5A interlock will open and insert a resistance in the shunt coil of transition relay V, preparing this relay to open again at a proper combination of generator volts and amperes.

TRACTION MOTOR CUTOUT

The locomotive is not equipped with a traction motor cutout switch. However, it is a simple matter to isolate the two traction motors on each truck.

Insert thin strips of insulating material between the tips of the series contactor S and between the tips on either the series-parallel contactor SP1 or series-parallel contactor SP2 and block the control relay CR1 closed. The SP1 contactor will isolate motors 3 and 4 on the trucks under the cab end and the SP2 contactor will isolate motors 1 and 2 on the trucks under the hood end.

The insulating material has to be thin because the S contactor has to close so the interlock fingers will make proper contact for series-parallel operation when the motors on one truck are cut out.

Move the controller handle to series-parallel, Notch 2 and open throttle.

TESTING AIR BRAKES WITH TRAIN IN MOTION

1. Partly close throttle to decrease current in traction motors.
2. Apply brakes and release them upon sufficient reduction of speed.
3. After test, operate throttle as desired.

PASSING OVER RAILROAD CROSSINGS

Before arriving at a railroad crossing, partly close the throttle to materially reduce the traction motor cur-

rent in order to minimize arcing under the brushes and prevent flashovers at the traction-motor commutators as the wheels jar over the crossing.

Caution should also be used when entering or leaving a turn table to minimize traction motor flashovers and broken brushes. Under these conditions the throttle should be opened just enough to permit movement of the locomotive.

REVERSING THE LOCOMOTIVE

1. Move the throttle to the idle position.
2. Apply air brakes to bring the locomotive to a full stop.
3. After the locomotive has come to a full stop, move the controller handle to one of the three reverse positions: Series, Series-parallel or Reduced-field.
4. Release all brakes.
5. Open throttle.

LEAVING THE LOCOMOTIVE TEMPORARILY

1. Before leaving the locomotive, move the throttle to the Idle position.
2. Move the controller handle to the Off position.
3. Set the hand brakes.

SHUTTING DOWN THE DIESEL ENGINE

To shut down the engine normally, open the fuel pump switch in the cab. The fuel pump will stop and the governor solenoid will shut down the engine.

To shut down the engine in case of an emergency and the engine will not shut down normally, pull the over-

speed trip lever at the engine. The fuel injection pumps will shut off the fuel supply to all cylinders and stop the engine. Reset the overspeed trip device.

OPERATING THROUGH WATER

Do not exceed 2 or 3 MPH if there is water over the rail. Never operate the locomotive through water that is more than 4 inches above the rail head.

APPLYING SAND

Sand bad rail before wheels slip or before brakes are applied.

When wheels slip with power on, partially close the throttle until slipping stops; sand the rails and then open throttle.

TOWING LOCOMOTIVE TO START ENGINE

The following information pertains to the low hood type locomotive having the two wire system.

1. Have the water temperature at about 170° F so as to lessen internal engine friction.
2. Block the starting contactors GS1 and GS2 open with a wooden wedge as a safety measure.
3. Attach a heavy cable jumper, equipped with 50 amp. insulated clips on each end to the stationary side of the series-parallel contactor SP1 and to the stationary side of the starting contactor GS1. The generator, motors 3 and 4 and the starting field are now in a closed isolated circuit.
4. Close battery switch.
5. Close throttle.
6. Have controller in OFF position.
7. Close fuel pump switch. Fuel oil pressure should be 35 psi.
8. Place the reverser in the position opposite to the

direction of movement of the locomotive, that is, if the locomotive is to be moved forward, the reverser should be in the reverse position. When moving the locomotive, if the wheels on the rear truck turn freely, move the locomotive in the other direction. The wheels will then have the tendency to slide and the reverser will definitely be in the proper position.

9. Sand track to avoid sliding of wheels.

10. Tow locomotive at 2 or 3 MPH until engine starts; then stop towing.

11. With the engine idling, remove jumper and wedges holding open the starting contactors. Care should be taken when removing the wedges as the moveable side of the contactors are "hot".

12. Close control switch.

TOWING DEAD LOCOMOTIVE

1. Close throttle and move controller handle to Off position.

2. Open control switch and main battery switch.

3. Close double-heading cock and open dead-engine cock. Leave independent and automatic brake handles in running positions.

4. Close all doors, windows and ventilators.

5. In freezing weather, drain cooling water from radiator, engine and turbocharger, if used.

RUNNING WITH ONE BLOWER DOWN

Load locomotive to only half its full capacity if a traction motor blower is inoperative after cutting out the non-ventilated motors.

MULTIPLE-UNIT LOCOMOTIVES

Multiple-unit locomotives have slightly different controls, consequently their operation also differs in a few respects. Operating instructions previously covered in this manual apply except as indicated in this section.

CONTROLS IN THE CAB

Throttle

The throttle is the notched type having eight power notches and an idling notch. Advance the throttle by moving it positively from notch to notch — do not leave it halfway between notches. When pulling a heavy train, leave the throttle in each notch for a few seconds when advancing the throttle. The throttle can not be opened until the reverse handle is either in forward or reverse position.

Reverse Handle

The reverse handle, located on top of the control stand has three positions; Forward, Reverse and Neutral. The throttle has to be closed before the reverse handle can be moved.

Series Holding Switch

The series holding switch, located on the lower front portion of the control stand, is used to select traction motor combinations. It has two positions, S and SP.

In SP position transfer from series to series-parallel to reduced field as locomotive speed increases and from reduced field back to series-parallel is automatic. Transfer from series-parallel to series is made manually by closing the throttle, moving the switch to S position and reopening the throttle.

In S position there will be no traction motor transition so therefore the traction motors will stay in series connection.

Push Button Switches

Located at the side of the control stand is a series

of push button switches used to control the fuel pump, engine starting, lighting circuits and motor control.

The order of push button switches is:

Engine Start - Cranks engine from the battery. Spring loaded.

Control - Energizes control circuits.

Fuel Pump - Starts fuel pump motor.

Front Headlight Dim

Front Headlight Bright - Dim switch has to be closed before bright light will light.

Rear Headlight Dim

Rear Headlight Bright - Dim switch has to be closed before bright light will light.

Far Headlight Dim - Lights far headlight on trailing unit.

Far Headlight Bright - Dim switch has to be closed before bright light will light.

Dome Light

Gauge and Number Lights

Marker Lights

Motor Control - When open, prevents locomotive from moving when throttle is opened.

NOTE: The far headlight switches in the first unit will operate the headlights on the second unit only. If a headlight on the third unit is desired, the operator must close the proper switch in that unit.

Sander Switch

Sanding is obtained by depressing the foot switch on floor. The reverse handle automatically controls sanders for forward or backward movement.

BRAKE PIPE CUTOUT COCK

This is a three position cutout cock which serves as the usual brake pipe cutout cock in addition to other functions. This cock has three operative positions: position No. 1 with handle horizontal or crosswise of the pipe; position No. 2 with handle upward, parallel with pipe; and position No. 3 slightly beyond No. 2.

Provision is made so that the handle cannot be accidentally placed in No. 3 position. The body is provided with stop lugs for positions No. 1 and 2, and with a stop lug for No. 3, in a higher plane. There is a stop pin in the usual plug. Normally the handle can be freely moved between positions No. 1 and 2, but to move it into position No. 3, requires that the stop pin be raised against the tension of a spring, so that it will pass over the lug for position No. 2.

When the locomotive is operated as a single unit, or as No. 1 in double heading, the cutout cock will be in position No. 1, opening the brake pipe connection to the brake valve and connecting the piston chamber of the transfer valve to atmosphere.

On a locomotive operating as the second unit in double heading the cutout cock will be in position No. 2, closing the brake pipe connection to the brake valve and connecting the transfer valve piston chamber to main reservoir pressure.

When a locomotive is hauled "Dead" in a train, the handle of the brake valves should be in running position and the cutout cock should be in position No. 3 (same as position No. 1 except the brake pipe connection is closed). The dead engine cock should be open.

When a locomotive is used as a pusher the cutout cock should be placed in the same position as for a "Dead" engine operation, but the dead engine cock should remain closed.

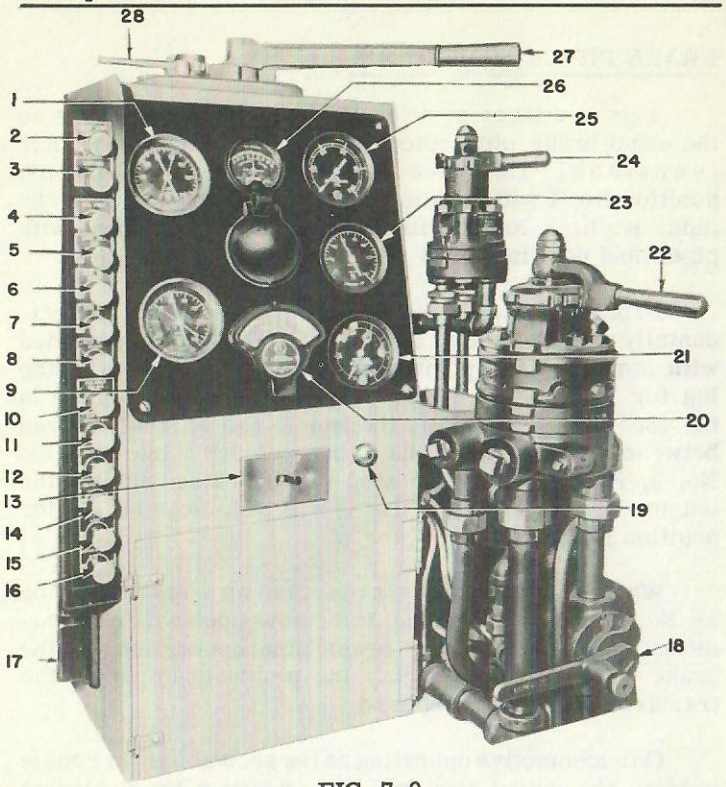


FIG. 7-0
ENGINEER'S POSITION - MU CONTROL

1. Main and Equalizing Reservoir Air Gauge

   Red - Main Reservoir Pressure
   White - Equalizing Reservoir Pressure

2. Engine Start Switch — cranks engine from battery.

3. Control Switch — energizes control circuits.

4. Fuel Pump Switch — starts fuel oil pump motor.

5., 6., 7. and 8. Headlight Switches — for bright, first close dim switch and then bright switch.

9. Brake Cylinder and Brake Pipe Air Gauge

   Red - Cylinder Pressure
   White - Brake Pipe Pressure

10. and 11. Far Headlight Switches — lights far headlight on trailing unit.

12. Dome Light Switch

13. Series Holding Switch — holds locomotive in series connection when in S position.

14. Gauge and Number Lights Switch

15. Marker Lights Switch

16. Motor Control Switch — when open, prevents locomotive from moving when throttle is opened for faster air pumping.

17. Wheel Slip Buzzer — warns of wheel slipping.

18. Double Heading Cock

19. Overload Indicating Light

20. Engine Water Temperature Indicator

21. Lubricating Oil Pressure Gauge

22. Automatic Brake Valve Handle

23. Control Air Pressure Gauge

24. Independent Brake Valve Handle

25. Fuel Oil Pressure Gauge

26. Battery Charging Ammeter

27. Throttle

28. Reverse Handle

FASTER AIR PUMPING

To pump air faster on a single locomotive equipped with multiple-unit control, pull out motor control switch, move reverse handle to Forward or Reverse position, and then advance throttle not more than four notches. Some air pressure is required before throttle will operate engine above idling speed.

When locomotives are coupled together, faster air pumping is obtained on all units by advancing the throttle on the leading unit with the motor-control switch open.

MULTIPLE-UNIT OPERATION

Operation with two or more locomotives in multiple is essentially the same as single-unit operation except that all locomotives are controlled from one engineman's position.

COUPLING UNITS TOGETHER

When locomotives are coupled together, the brake pipe, main reservoir and equalizing pipe (also signal pipe if used) hose must be coupled up between the locomotives and their cutout cocks open. Connect the train line jumpers and be sure that each plug is pushed all the way into the socket.

Where there are two or more locomotives in a train, the instructions already given remain unchanged so far as the leading locomotive, or the locomotive from which the brakes are being operated, is concerned. On the trailing unit, move the brake pipe cutout cock to No. 2 position. Move the automatic brake valve handle to Lap position, move the independent brake valve handle to Running position and remove both handles. The brake of the trailing unit is then operated from the lead unit the same as on the lead unit. Close the throttle. Move the Reverse handle to Neutral position and remove the handle.

STARTING ENGINES

The engines of each of the units coupled in multiple may be started in the same manner as starting a single locomotive engine. However, after all engines are running, all push button switches should be OPEN, the series holding switch in either S or SP position and the battery switch CLOSED on each trailing unit with the exception of fuel pump switch which must be closed on the third unit.

If the lead or controlling unit engine is started first, it is not necessary to close any of the push button switches on the trailing units other than the fuel pump switch on the third unit as the starting circuit is controlled from the lead unit. However, the battery switch must be CLOSED on each of the trailing units.

To Start Engine

1. Close battery switch.
2. Close throttle.
3. Move reverse handle to neutral position.
4. Close fuel pump switch. Wait for fuel oil pressure to build up.
5. Close control switch.
6. Close and hold in engine start switch. As soon as the lubricating oil pressure builds up to 25-30 psi, release the starting switch.

To Start Engines In Trailing Units If Control And Fuel Pump Push Button Switches Are Closed On Lead Unit.

1. Close battery switch.
2. Have throttle in Idle.
3. Have reverse handle in neutral position.
4. Close fuel pump switch on third unit.
5. Fuel oil pressure should show on gauge on second unit as pump is running from lead unit fuel pump control.
6. Close and hold in engine start switch. As soon as the lubricating oil pressure builds up to 25-30 psi, release the start switch.

MOVING THE LOCOMOTIVES

1. Install brake valve handles and reverse lever.
2. Check for main reservoir pressure.
3. Have 70 pounds of control air pressure.
4. Apply brake cylinder pressure and release handbrake.
5. Test sanders.
6. Make air brake test.
7. Have at least 120° F water temperature (if possible) before notching up on the throttle.
8. Turn the series holding switch to SP position for normal operation in the leading or "controlling" unit.
9. Close motor control switch in the leading or "controlling" unit.
10. Move reverse handle to forward or reverse position as required.
11. Open throttle.

    When the throttle is opened to Notch 1, the control circuits are energized, the generator is connected to the traction motors and the locomotive starts to move.

    Successive advancement of the throttle to the higher notches acts on the governor to admit more fuel to the engine. The engine speed will increase until it reaches the setting of the governot as controlled by the throttle. More power is delivered to the generator and thus to the traction motors.

OPERATING IN SERIES - LOW SPEEDS:

With the control switch closed and its fuse good, move the reverse handle to forward position. Move the series holding switch to S position, close the motor control switch and open the throttle.

With the throttle open in any notch, control voltage energizes the throttle segments so that 5A wire is energized from the 50 wire. 5A wire, which is connected to one side of the motor control switch, energizes 5 wire when the motor control switch is closed and its fuse is good. 5 wire energizes 8 wire with the reverse handle in forward position. The 8 wire then energizes the forward magnet valve on the reverser, admits air at 70 psi pressure to the reverser air cylinder and turns the reverser to its forward position or holds it there if it is already in that position.

With the reverser in its forward position, its forward interlock will close and complete a circuit to pick up the following contactors through the forward segment of the controller.

EF contactor, WS1 and WS2 relays are open and have their contacts 8A-8P and 8P-8R closed and GR relay is open and has its 8R-8H interlock closed.

S contactor, provided SP1 is open and has its 8A-8B contacts closed.

The purpose of having reverser interlocks control the excitation contactors EF and GF is to make sure that the reverser is in a running position before any current flows and that its position is the same as that selected by the controller selector handle. This minimizes the burning of the reverser contact segments and fingers and assures movement only in the direction desired. These reverser interlocks are 8-8A for forward movement and 0-8A for reverse movement.

EF contactor's main contacts 60-R8 will connect the exciter shunt field to the battery through resistors R6-R7 and R7-R8. Resistor R7-R8 reduces the exciter voltage so that "soft" starting and easy spotting of the locomotive can be obtained.

Control relay CR2 will close and short circuit resistor R7-R8 when the throttle is opened to the third notch. This will raise the exciter voltage to normal.

S contactor will connect the four traction motors in series across the main generator.

As soon as S contactor closes, S contactor interlock closes connecting 8B-8C. GF contactor coil will then become energized and close GF contactor provided control relay CR1 is open and its interlock 8C-8D are closed; starting contactors GS1 and GS2 are open and their interlocks 8D-8E and 8E-8F are closed and ground relay GR contacts 8F-8G are closed. The GF contactor connects the main generator field directly to the exciter. This will give full main generator voltage to move the locomotive in series.

OPERATING IN SERIES-PARALLEL - MEDIUM SPEED

With the locomotive moving in series, turn the series holding switch to SP position. This will connect battery positive to the series holding switch contacts 5-6 which will allow the series to series-parallel contacts 6-8J on transition relay V to be effective when the relay V picks up.

As the locomotive increases in speed, the motor current and, consequently, the generator current, decreases, while the generator voltage simultaneously increases. When the ratio of voltage pull-in effect to the current holdout effect increases to the operating point of the relay, this relay will close both its contacts, 8A-8M and 6-8J. Contacts 8A-8M will be ineffective because they have in series with them the open interlock contacts 8M-8N on contactor SP2.

The 6-8J contacts of relay V will close relay CR1. This relay holds itself in through its own 6-8J contacts which are closed when the relay is closed. The 6-8J contacts of relay V and CR1 are in parallel.

When CR1 relay closes, its 8C-8D contacts will open and, in turn, open generator field contactor GF. The main contacts GS-EA of contactor GF opening will insert resistance in the field of the main generator. This decreases the main generator voltage in preparation for the transition operations to follow.

When contactor GF opens, its interlock 8J-8K will close traction motor contactor SP1, which will hold itself in through its own 8J-8K interlock. This interlock is in parallel with a similarly numbered interlock on contactor GF.

When contactor SP1 closes, No. 1 and No. 2 traction motors will be short circuited through SP1 main contacts. No harm will be done, however, because an instant previously the current in these motors had been reduced and the voltage across them decreased by the opening of the main contacts of GF. The closing of SP1 main contacts also will connect No. 3 and No. 4 traction motors directly across the generator.

As soon as SP1 closes, its interlock contacts 8A-8B will open and drop out contactor S. The dropping out of contactor S will allow its interlock 8K-8L to close contactor SP2, which will connect traction motors No. 1 and No. 2 directly across the generator. The interlock 8L-8D on contactor SP2 will also close and, in turn, close contactor GF whose main contacts GS-EA will put full exciter voltage on the main generator field and rebuild the main generator voltage up to normal.

When operating in series, the full current from the

main generator passes through each traction motor in succession, from positive of main generator, through No. 4 traction motor, to No. 3 motor, through the main contacts of series contactor S, to No. 2 motor, to No. 1 motor and back to main generator negative.

The characteristic of the main generator is such that it holds approximately constant horsepower on the Diesel engine. However, since the output of the generator is the product of its voltage times its current, a constant output requires only a constant product of volts and amperes. It makes no difference if the volts are high and the amperes are low or if the volts are low and the amperes are high, just so long as the product of the two remains the same. This output characteristic of the main generator is determined by the exciter E.

When starting the locomotive from standstill, a very high current can be taken by the traction motors. This can easily damage the traction motors if the motors can not move because either the brake is set or the train is too heavy. If the traction motors can rotate, they automatically, by their inherent characteristics, decrease this current so that, as the locomotive accelerates, the generator current decreases and its voltage increases. When this voltage reaches the top voltage for which the generator was designed, a change in motor connections is made by the operation of transition relay V. This change of traction motor connections is from series, with all of the main generator current passing through all traction motors, one after the other, to series-parallel in which the current from the main generator splits, half going through No. 2 and No. 1 motors, one after the other, and the other half going through No. 4 and No. 3 traction motors, one after the other. With the horsepower or the product of the generator volts and amperes remaining constant, this transfer from series to series-parallel results in a change in the generator from a condition of high voltage and low current, to a condition of low voltage

and high current, the horsepower load on the engine being the same.

During this change of connections, transition relay V opens, not only because of the drop in generator voltage but also because of resistance being inserted in its voltage pickup coil by the opening of the interlock 15A-15B on contactor GF while GF is open. When GF closes again after the transition is complete, transition relay V is again in its normal condition, ready to close its contacts whenever the combination of high generator voltage and low generator current occurs again.

OPERATING IN SERIES-PARALLEL REDUCED FIELD - HIGH SPEEDS

With the locomotive moving in series-parallel, the SP2 interlock contacts 8M-8N are closed.

As the locomotive continues to accelerate, at a speed of about 23 MPH, the voltage will again reach the top voltage for which the generator was designed, with a simultaneous decrease in current which will cause relay V to close again. Now, contacts 6-8J are in effect as they are paralleled by the 6-8J closed contacts of CR1 relay. When contacts 8A-8M on V relay close, they will close reduced field contactors M1 and M2. Each of these contactors has a resistor in series with its main contacts. When M1 contactor closes, resistor 106A will be connected in parallel with the fields of No. 2 and No. 1 traction motors. When M2 contactor closes, resistor 106B will be connected in parallel with the fields of No. 4 and No. 3 traction motors. Hence, part of the current in the motor armatures will be diverted through these resistors, with a resulting decrease in current through the motor field coils. When the field strength of any motor is decreased, its armature tries to increase in speed.

The weakening of the fields results in more current to flow through the motor armatures; thus, more current is taken from the main generator. To maintain constant horsepower, the generator voltage drops, thereby maintaining the same product of volts and amperes.

When M1 contact closes, its interlock 15-15A will open and insert a resistance in the shunt coil of transition relay V, preparing this relay to open again at a proper combination of generator volts and amperes.

SHUTTING DOWN ALL ENGINES

Open the fuel pump switches on the first and third units (if used) to shut down all engines.

SHUTTING DOWN ENGINE ON TRAILING UNIT

Either disconnect the train line jumper between units to stop the trailing unit engine or trip the engine overspeed device manually. After the engine has stopped, reset the trip mechanism.

WATER TEMPERATURE

While operating, watch the trailing unit to see that the water temperature does not exceed 180° F. Experience will indicate how to set the shutters.

OPERATING HEADLIGHTS

Open all headlight switches on the trailing unit. Close far headlight dim switch and far headlight bright switch on leading unit to light the far headlight on trailing unit of second unit. If a headlight on the third unit is desired, the operator must close the proper switch in that unit.

OPERATING UNDER UNUSUAL CONDITIONS

Engine Will Not Turn Over When Starting Button Is Pressed

1. See that the controller handle is in OFF position (standard locomotives); see that reverse handle is in neutral position and throttle closed (MU locomotives).
2. See that the battery and control switches are closed.
3. See that engine start and control fuses in control stand are good; also 110 amp. battery fuse in the contactor compartment.
4. Battery may be "dead".
5. See that contactors GS1 and GS2 close.

Engine Turns Over But Will Not Fire

1. See that fuel pump push button is closed and fuel pump fuse is good.
2. If fuel pump runs but pressure does not build up to 35-40 psi., inspect fuel supply, filters and piping for leaks or stoppage. See that emergency fuel cutoff valve is open.
3. If the piston rod on the governor power piston does not move upward when the engine is turning over, check wiring to the governor solenoid.
4. Make sure overspeed trip rack and cutout buttons on Diesel engine are in reset position.
5. If engine is very cold it may not be turning over fast enough to start. Preferably heat the cooling water with low pressure steam. Otherwise loosen half the indicator plugs in the cylinder heads — cylinders 1, 4, 5, or cylinders 2, 3, 6.

6. Low battery. Check battery gravity.

Locomotive Will Not Move With Engine Running And Throttle Open

1. Close throttle and open slowly — see that brakes are off and that wheels are not slipping.
2. See that control air pressure is 70 psi. If not and main reservoir pressure is up, reducing valve may be stuck.
3. See that ground relay is not tripped. If tripped, reset.
4. See that control fuse is good, also 10, 80 and 110 amp. fuses in contactor compartment.
5. On multiple-unit locomotives, see that motor control switch is closed and its fuse good.
6. See that first throttle switch 101 is closed (standard locomotives).
7. See that series contactor S is closed.
8. See that exciter field contactor EF is closed.
9. See that generator field contactor GF is closed.
10. See that starting contactors GS1 and GS2 are not stuck closed.

Locomotive Stays At Low Speeds

1. See that second throttle switch 110 is closed.
2. See that GF contactor is closed.
3. This condition generally indicates that control is not transferring from series to series-parallel. Also, the engine output may be down. Operate in series position until the condition can be corrected.

Locomotive Moves Under Power With Throttle Closed

1. The throttle switch is probably stuck. To stop locomotive, pull out fuel pump switch and apply brakes.

Locomotive Has Little Power When Throttle Is Opened

1. See that both exciter EF and generator field GF contactors close when throttle is open.
2. See that 10, 80 and 110 amp. fuses in contactor compartment are good and that battery is charged.
3. Inspect throttle mechanism. Make sure that throttle shaft or adjusting lever is connected at governor. On multiple-unit locomotives, call maintainer.
4. See that auxiliary generator exciter set drive belts are not slipping.
5. See that fuel oil pressure is correct.
6. See that all cylinders are firing.
7. See that the second throttle switch is closed.
8. Engine not coming up to speed.

Ground Relay Closes

If possible, call the maintainer to inspect generator traction motor leads and connectors and traction motors to determine the cause of the ground. It will operate if there is any leakage from high voltage wiring to locomotive frame. This may occur during a "flashover" which in turn sometimes results from bad wheel slipping, throttle slamming or other careless throttle handling.

If the locomotive is in transfer or road service, make sure there is no burning smell or serious damage, then reset the relay and proceed. If the relay trips again, open the ground relay switch, reset the relay and move the locomotive only far enough to get in the clear.

Engine Stops

1. Check fuel oil supply and pressure.
2. Bar engine over manually to see if it is free.
3. Check lubricating oil supply. Press engine start button to see whether pressure builds up.
4. Check position of overspeed trip. If tripped, reset and start engine.
5. Check governor shutdown solenoid and solenoid interlock.

Engine Overspeeds After Kicking Cars

If Diesel engine continually overspeeds after the throttle is closed, causing overspeed trip to operate, shut down the engine and notify maintainer as this is caused by a faulty governor, improper fuel pump rack setting or too low overspeed trip setting.

Engine Dies After Kicking Cars

This usually indicates faulty governor; however, check lubricating oil system before starting up again.

Reverser Fails to Move

1. Reverse handle not in forward or reverse position.
2. Control air pressure low. Check main reservoir air pressure, control air feed valve, control air cutout cock and circuits to the reverser coils.

VAPOR-CLARKSON STEAM GENERATOR

OK 4630 - OK 4616

BEFORE STARTING

On OK models, the valves designated by odd numbers must be OPEN during normal operation of the steam generator. Valves designated by even numbers must be CLOSED during normal operation of the steam generator. Normally open valves are fitted with a cross type handle; normally closed valves are fitted with the standard round handle. These designations apply only to the OK series steam generators.

1. Make certain that the following valves are OPEN:

   Atomizing Air Shutoff Valve (1)

   Coil Shutoff Valve (3)

   Return Water Outlet Valve (9)

   Steam Admission Valve (11 to Trainline Pressure Gauge (224)

   Steam Admission Valve (13) to Water By-Pass Regulator (111)

   Three-Way Washout Valve (17)

   Water By-Pass Regulator Shutoff Valve (19)

   Water Supply Stop Valve (21)

2. Be sure that the following valves are CLOSED:

   Coil Blowdown Valve (2)
   Layover Connection Shutoff Valve (6)
   Manual Water By-Pass Valve (8)
   Steam Admission Valve (10) to Radiation (217)
   Washout Inlet Valves (14) and (16)
   Water Pump Test Valve (18)
   Water Drain Valves (20) and (22)

3. See that both the overload reset button (106) and the stack switch (109) reset button are "IN". The overload reset button is located inside the control panel on the magnetic overload relay.

TO FILL

1. Open the atomizing air shutoff valve (1) and fill-test valve (4); latch open the separator blowdown valve (12) to drain the steam separator. Close the separator blowdown valve when the separator is completely drained.
2. Close the main switch and turn the control switch (102) to FILL.
3. While the coils are filling see that spark (220) is available for ignition. Check ALL valves.
4. When water discharges from the fill-test valve (4) turn the control switch (102) to OFF and close the fill-test valve.

NOTE: If the coils are empty it will take about five minutes to fill the steam generator with water.

TO START

CAUTION: Do not start the steam generator unless the coils are filled.

1. Latch open the separator blowdown valve (12) and turn the control switch (102) to RUN. For easy starting, be sure the control switch has been OFF long enough for the motor to come to a full stop.
2. Close the separator blowdown valve when the generator steam pressure gauge (212) registers 50 psi.
3. Open the separator blowdown valve several times for three to five second intervals during the first few minutes of operation.
4. Set the water by-pass regulator (111) to the required train line pressure.

5. After the trainline is coupled, open the remote control trainline shutoff valve (7) by depressing the reset lever (7a) and then open the stop and check valve (15).

NOTES:

1. Check the return water flow after the steam generator has settled down to a steady output. On 3000 pound units the return water flow indicator (218) should cycle from 4 to 12 times a minute; on 1600 pound units it should cycle from 4 to 8 times a minute.
2. If the steam generator does not start or function properly, check all valves to see that they are open or closed as indicated in piping diagram for OK and DSK steam generators.
3. The steam generator should come up to full operating pressure in one or two minutes; it may take 10 or 15 minutes to build up the required operating steam pressure in the trainline.

RUNNING ATTENTION

1. Open the separator blowdown valve (12) for five seconds at least once every hour.
2. Turn the handle on the fuel filter (206) during stops. At the same time, turn the handle on the treatment injector filter (225), where this method of water treatment is used.

TO SHUT DOWN THE STEAM GENERATOR

For short stops it is only necessary to close the stop and check valve (15). The fire will cycle and maintain operating pressure in the steam generator. For terminal stops, proceed as follows:

1. Close the stop and check valve (15) and the remote control trainline shutoff valve (7).

2. Set the water by-pass regulator (111) to maximum output. When the generator steam pressure gauge (212) registers 200 psi turn the control switch (102) to OFF.

3. Open the coil blowdown valve (2). When the generator pressure drops to 75 psi, close the valve.

4. Open the separator blowdown valve (12) and blow down the steam separator (221) with the remaining pressure. Close the separator blowdown valve.

5. Fill the coils with water.

6. Close the atomizing air shutoff valve (1) and open the main switch.

NOTE: When starting, do not omit draining the steam separator, opening the fill-test valve, and again filling the steam generator with water. If the coils are already full, it will only take a moment for water to discharge from the fill-test valve.

FREEZING WEATHER PRECAUTIONS

The inlet valve (10) to the radiation (217) should be opened when operating during severe weather.

If a locomotive with a multiple installation does not have all of its steam generators in operation, open the coil blowdown valve (2), the layover connection shutoff valve (6) and the inlet valve (10) to the radiation on idle steam generators.

CAUTION: Layover connection shutoff valve (6) must be closed when trainline shutoff valve (7) is closed to cut a car out of a train.

If a locomotive is left standing out of service, operate one of the steam generators or make a connection to the yard steam line. In extremely cold weather the water pump (230) and steam generator controls should be given additional protection against freezing.

If no steam is available, thoroughly drain the steam generator. Open the drain valves (20) and (22), the water pump test valve (18), the coil blowdown valve (2), the separator blowdown valve (12) and the coil shutoff valve (3). Break the pipe connections where necessary to completely drain the piping. Turn the water pump by hand to clear it of water, or blow it out with compressed air. Remove the cover of the water treatment or water strainer tank (234) and make sure it is drained.

TROUBLE SHOOTING

If one of the protective switches (magnetic overload relay, coil blowdown valve switch, stack switch high temperature contacts) operates to shut down the steam generator, the alarm will ring and the "boiler off" signal will flash on the engineer's control panel and engine control panel.

Turn the control switch (102) to OFF and use the following instructions as a guide in locating the trouble.

MOTOR AND BURNER SHUT DOWN DURING OPERATION

1. Blown fuses or tripped circuit breakers: The alarm will not ring and instrument lights will go out. The circuit breaker or breakers are located on the control compartment panel and in some cases one is mounted in the main switch box near the steam generator. Check these breakers as well as the control fuses in the steam generator control cabinet. The OK series of steam generators has a test lamp and fuse clips wired inside the control cabinet. Use this fuse test clip and test lamp to check the fuses.

2. Overload reset button (106) "out". The alarm will ring; the instrument lights will remain on. Turn the control switch (102) OFF: check for hot blower (202) or water pump (230) bearings and for poorly adjusted pulley belts. On OK units check the setting of the belt tension adjuster. Push the overload reset button "IN".

3. Stack switch (109) reset button "out": The high temperature contacts in the stack switch are open; the alarm will ring and the instrument lights will remain on. Turn the control switch (102) to OFF: open the separator blowdown valve (12) and drain the steam separator (221). Close the separator blowdown valve, push in the stack switch reset button, refill the coils with water and then start the steam generator.

4. Coil blowdown valve (2) partially open: The alarm will ring, the instrument lights will remain on. Be sure the locking pin on the coil blowdown valve handle is properly seated in the closed position.

MOTOR STARTS BUT BURNER DOES NOT

If the fire fails to light, the low temperature contacts on the stack switch (109) will not close and after a 45 second time delay the outfire relay will open the circuit to shut down the steam generator. The alarm will ring and the instrument lights will remain on. Turn the control switch (102) OFF and check the following list for possible causes for the burner failure.

1. Ignition failure: Turn control switch to RUN; no spark visible through the peep hole glass, or spark is of low intensity. If an ignition fuse is blown or if the current flow is broken for any other reason, the ammeter in the ignition circuit on OK units registers zero when the ammeter test button is pressed in. If the ammeter registers below normal, the spark plug electrodes are dirty or too far apart. If the ammeter registers above normal the electrodes are too close together or the ignition circuit is grounded.

   Check the ignition fuses; on OK units use the test lamp and clips installed in the control cabinet for that purpose. Tighten loose cable connections and replace chafed or broken wire which may be breaking or grounding the circuit.

2. Low atomizing air pressure (201): The air switch (101) on OK units opens and breaks the circuit to the fuel solenoid valve (104), which then stops the flow

of fuel to the sprayhead (105). On DSK units, low air pressure will fail to lift the diaphragm in the fuel sprayhead (105); the needle valve remains closed and prevents the admission of fuel to the firepot.

Be sure the sir admission valve is fully open. Clean the strainer screen in the atomizing air line and drain the atomizing air pressure regulator (100). If the low atomizing air pressure persists, tighten the adjusting screw at the top of the air pressure regulator to increase the atomizing pressure.

3. Low fuel manifold pressure (208): Turn the handle on the suction line fuel filter (206) several times. A slight suction leak may cause the manifold pressure to build up slowly; put the control switch (102) on FILL to bleed the fuel line and bring the manifold pressure up to normal.

4. Low fuel nozzle pressure (207): Lack of water causes the servo-fuel control (108) to limit the supply of fuel entering the nozzle. If the water supply is almost completely stopped, the cam plate may come down far enough to actuate the cutout switch on the servo and close the fuel solenoid valve (104).

Be sure that the pump belts have proper tension, the water pump test valve (18) is closed, the cover on the water treatment or strainer tank (234) is tight, the three-way washout valve (17) is fully open, and that the drain valves (20) and (22) are tightly closed.

Open and close the water by-pass regulator (111) adjusting handle several times to free the regulator from possible sediment. If the water pressure gauge (229) still registers low, close the water by-pass regulator shutoff valve (19). This closes the water by-pass line and permits all of the feed water to flow to the servo-fuel control (108); the steam generator will start at once if the by-pass regulator is causing the trouble. Set and manually regulate the trainline steam pressure by adjusting the manual water by-pass valve (8).

High feed water temperature or leaky water line connections may cause the water pump (230) to become air or vapor bound. Violent fluctuation of the water pressure gauge needle indicates this condition. Tighten leaky water line connections and bleed the line by opening the water pump test valve (18). Allow water to flow from this valve until no air or vapor bubbles are evident in the water.

IRREGULAR TRAINLINE PRESSURE

1. Burner cycles off and on: Insuffient water delivery causes the steam generator to run in superheat; the steam temperature limit control (110) operates to protect the coils against overheating. Check the water pump output as instructed in the preceding paragraphs.

2. Safety valves blow; Shut down the steam generator. Lower the trainline pressure setting on the adjusting handle of the water by-pass regulator (111) and start the steam generator again. If the safety valves (107) continue to pop, close the water by-pass regulator shutoff valve (19) and manually regulate the trainline steam pressure by opening and adjusting the manual water by-pass valve (8).

ITEMS TO REPORT:

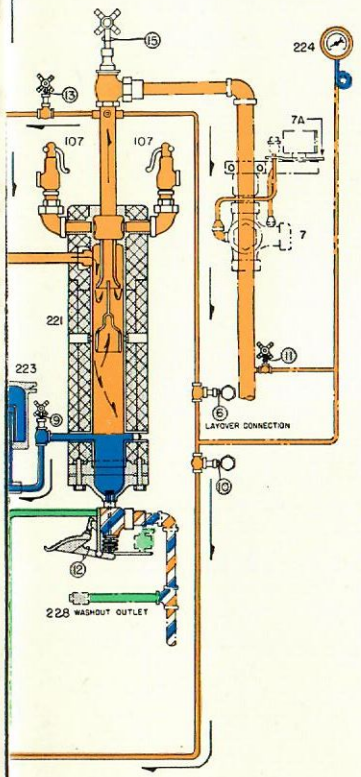
1. Water pressure greater than 450 psi at any time.
2. Excessive stack temperature.
3. Fluctuation of the fuel manifold pressure.
4. Frequent cycling of the burner.
5. Water flow indicator not cycling.
6. Water by-pass regulator inoperative.
7. Faulty operation of the steam generator for any reason.

S

following valves must be CLOSED during
al operation of the steam generator:
oil Blowdown Valve and Switch
ill-Test Valve
ayover Connection Shutoff Valve
Ianual Water By-Pass Valve
team Admission Valve to Radiation (Open
a cold weather)
team Separator Blowdown Valve
Vashout Inlet Valve
Vashout Inlet Valve
Vater Pump Test Valve
Vater Suction Drain Valve
Vater Treatment Tank Drain Valve

CONTROLS

100—Atomizing Air Pressure Regulator
101—Atomizing Air Switch
102—Control Switch
103—Fuel Pressure Regulator
104—Fuel Solenoid Valve
105—Fuel Spray Head
106—Overload Reset Button, Motor
107—Safety Valves
108—Servo-Fuel Control and Switch
109—Stack Switch
110—Steam Temperature Limit Control
111—Water By-Pass Regulator and Switch
112—Water Pressure Relief Valve



APPURTENANCES

200—Atomizing Air Strainer
201—Atomizing Air Pressure Gauge
202—Blower
203—Damper
204—Fuel Filter (Fuel pressure line)
205—Fuel Filter (Servo actuating line)
206—Fuel Filter (Suction line)
207—Fuel Nozzle Pressure Gauge
208—Fuel Pressure Gauge (At fuel pressure regulator)
209—Fuel Pump
210—Fuel Strainer
211—Fuel Tank
212—Generator Steam Pressure Gauge
213—Heat Exchanger
214—Ignition Transformer
215—Motor Converter
216—Oil Filler Cap
217—Radiation
218—Return Water Flow Indicator
219—Return Water Strainer
220—Spark Plugs
221—Steam Separator
222—Steam Trap (Radiation)
223—Steam Trap (Return water line)
224—Trainline Steam Pressure Gauge
225—Treatment Injector Filter
226—Treatment Injector Gauge
227—Washout Solution Inlet
228—Washout Solution Outlet
229—Water Pressure Gauge
230—Water Pump
231—Water Strainer Manifold
232—Water Tank
233—Water Treatment Injector Pump
234—Water Treatment Tank
(Strainer tank only if injector system is used)

enerator.

KEY TO IDENTIFICATION SYMBOLS

VALVES

Valves designated by odd numbers must be OPEN during normal operation of the steam generator. Valves designated by even numbers must be CLOSED during normal operation of the steam generator.

Normally open valves are fitted with a cross type handle; normally closed valves are fitted with the standard round handle. These designations apply only to the OK series steam generators.

The following valves must be OPEN during normal operation of the steam generator:

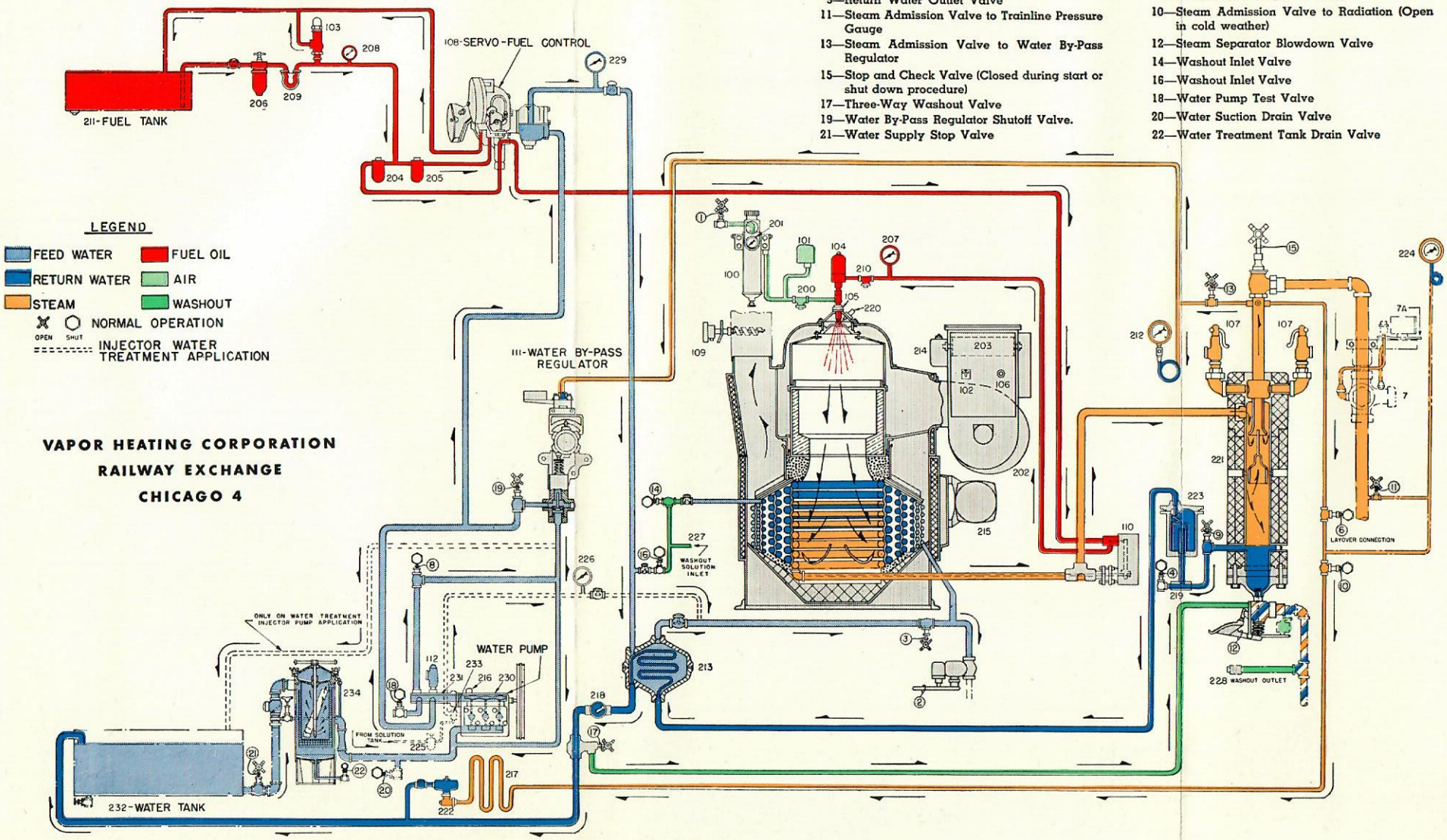
1—Atomizing Air Shutoff Valve
3—Coil Shutoff Valve
7—Remote Control Trainline Shutoff Valve
7a—Reset Lever
9—Return Water Outlet Valve
11—Steam Admission Valve to Trainline Pressure Gauge
13—Steam Admission Valve to Water By-Pass Regulator
15—Stop and Check Valve (Closed during start or shut down procedure)
17—Three-Way Washout Valve
19—Water By-Pass Regulator Shutoff Valve.
21—Water Supply Stop Valve

The following valves must be CLOSED during normal operation of the steam generator:

2—Coil Blowdown Valve and Switch
4—Fill-Test Valve
6—Layover Connection Shutoff Valve
8—Manual Water By-Pass Valve
10—Steam Admission Valve to Radiation (Open in cold weather)
12—Steam Separator Blowdown Valve
14—Washout Inlet Valve
16—Washout Inlet Valve
18—Water Pump Test Valve
20—Water Suction Drain Valve
22—Water Treatment Tank Drain Valve

CO
100—Atomizing Air
101—Atomizing Air
102—Control Switch
103—Fuel Pressure
104—Fuel Solenoid
105—Fuel Spray He
106—Overload Reset
107—Safety Valves
108—Servo-Fuel Cont
109—Stack Switch
110—Steam Temperc
111—Water By-Pass
112—Water Pressure

APPL
200—Atomizing Air S
201—Atomizing Air P
202—Blower
203—Damper
204—Fuel Filter (Fuel
205—Fuel Filter (Serv
206—Fuel Filter (Sucti
207—Fuel Nozzle Pre
208—Fuel Pressure G
lator)
209—Fuel Pump
210—Fuel Strainer
211—Fuel Tank
212—Generator Steai
213—Heat Exchange
214—Ignition Transfo
215—Motor Converte
216—Oil Filler Cap
217—Radiation
218—Return Water Fl
219—Return Water S
220—Spark Plugs
221—Steam Separato
222—Steam Trap (Ra
223—Steam Trap (Ret
224—Trainline Steam
225—Treatment Injec
226—Treatment Injec
227—Washout Solutic
228—Washout Solutic
229—Water Pressure
230—Water Pump
231—Water Strainer
232—Water Tank
233—Water Treatmer
234—Water Treatme
(Strainer tank o



Schematic Piping Diagram, OK-4630 and OK-4616 Series Vapor-Clarkson Steam Generator.

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KEY TO IDENTIFICATION SYMBOLS

mbers must be OPEN
he steam generator.
bers must be CLOSED
he steam generator.

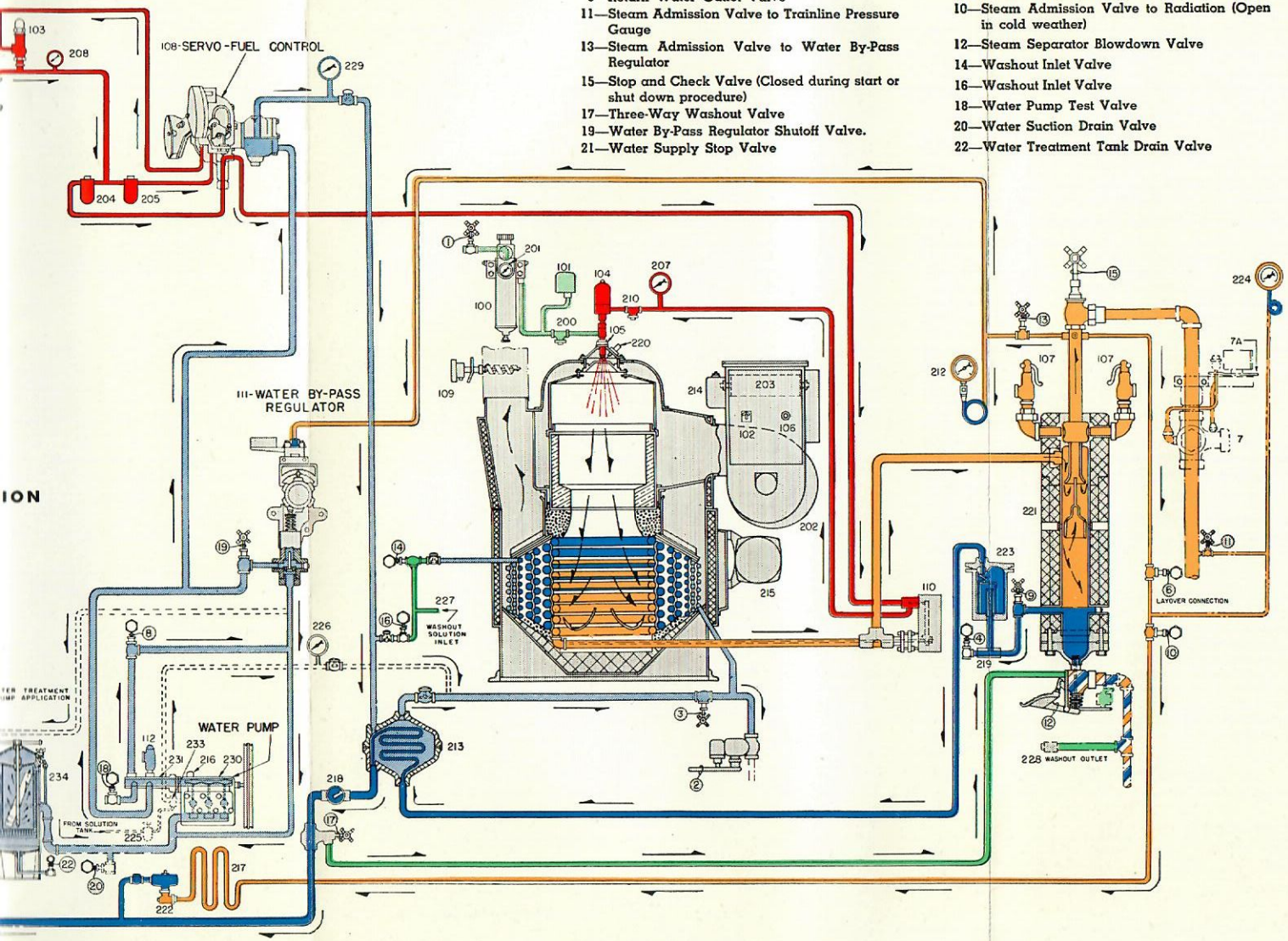
Normally open valves are fitted with a cross type handle; normally closed valves are fitted with the standard round handle. These designations apply only to the OK series steam generators.

The following valves must be OPEN during normal operation of the steam generator:

1—Atomizing Air Shutoff Valve
3—Coil Shutoff Valve
7—Remote Control Trainline Shutoff Valve
7a—Reset Lever
9—Return Water Outlet Valve
11—Steam Admission Valve to Trainline Pressure Gauge
13—Steam Admission Valve to Water By-Pass Regulator
15—Stop and Check Valve (Closed during start or shut down procedure)
17—Three-Way Washout Valve
19—Water By-Pass Regulator Shutoff Valve.
21—Water Supply Stop Valve

The following valves must be CLOSED during normal operation of the steam generator:

2—Coil Blowdown Valve and Switch
4—Fill-Test Valve
6—Layover Connection Shutoff Valve
8—Manual Water By-Pass Valve
10—Steam Admission Valve to Radiation (Open in cold weather)
12—Steam Separator Blowdown Valve
14—Washout Inlet Valve
16—Washout Inlet Valve
18—Water Pump Test Valve
20—Water Suction Drain Valve
22—Water Treatment Tank Drain Valve



CONTROLS

100—Atomizing Air Pressure Regulator
101—Atomizing Air Switch
102—Control Switch
103—Fuel Pressure Regulator
104—Fuel Solenoid Valve
105—Fuel Spray Head
106—Overload Reset Button, Motor
107—Safety Valves
108—Servo-Fuel Control and Switch
109—Stack Switch
110—Steam Temperature Limit Control
111—Water By-Pass Regulator and Switch
112—Water Pressure Relief Valve

APPURTENANCES

200—Atomizing Air Strainer
201—Atomizing Air Pressure Gauge
202—Blower
203—Damper
204—Fuel Filter (Fuel pressure line)
205—Fuel Filter (Servo actuating line)
206—Fuel Filter (Suction line)
207—Fuel Nozzle Pressure Gauge
208—Fuel Pressure Gauge (At fuel pressure regulator)
209—Fuel Pump
210—Fuel Strainer
211—Fuel Tank
212—Generator Steam Pressure Gauge
213—Heat Exchanger
214—Ignition Transformer
215—Motor Converter
216—Oil Filler Cap
217—Radiation
218—Return Water Flow Indicator
219—Return Water Strainer
220—Spark Plugs
221—Steam Separator
222—Steam Trap (Radiation)
223—Steam Trap (Return water line)
224—Trainline Steam Pressure Gauge
225—Treatment Injector Filter
226—Treatment Injector Gauge
227—Washout Solution Inlet
228—Washout Solution Outlet
229—Water Pressure Gauge
230—Water Pump
231—Water Strainer Manifold
232—Water Tank
233—Water Treatment Injector Pump
234—Water Treatment Tank
(Strainer tank only if injector system is used)

Schematic Piping Diagram, OK-4630 and OK-4616 Series Vapor-Clarkson Steam Generator.

VAPOR-CLARKSON STEAM GENERATOR

DRK 4530 - DRK 4516

BEFORE STARTING

1. Make certain that the following valves are **OPEN:**

   Atomizing Air Shutoff Valve (1)

   Coil Shutoff Valve (16)

   Water Supply Stop Valve (33)

   Water By-Pass Regulator Shutoff Valve (39)

   Return Water Outlet Valve (51)

   Steam Shutoff Valve to the Water By-Pass Regulator

   Steam Shutoff Valves to the Steam Pressure Gauges

2. Be sure that the following valves are **CLOSED:**

   Washout Inlet Valves (14)

   Coil Blowdown Valve (17)

   Water Pump Test Valve (30)

   Stop and Check Valve (46)

   Manual Water By-Pass Valve (40)

   Manual Trainline Stop Valve (43)

   Drain Valves (54)

3. See that both the overload reset button (12) and the stack switch (5) reset button are "IN". If a thermal

overload is used the reset button is located on the exterior of the control panel. If a magnetic overload relay is used, the reset button is located inside the control panel on the relay itself.

TO FILL

1. Open the atomizing air shutoff valve (1), fill-test valve (50), and latch open separator blowdown valve (53) to drain the steam separator. Close the separator blowdown valve when the separator is completely drained.
2. Check the stack switch (5) reset button and overload reset button (12).
3. Close the main switch and turn the control switch (20) to FILL.
4. While the coils are filling see that spark is available for ignition. Check ALL valves.
5. When water discharges from the fill-test valve (50) turn the control switch (20) to OFF and close the fill-test valve.

NOTE: If the coils are empty it will take about five minutes to fill the steam generator with water.

TO START

CAUTION: Do not start the steam generator unless the coils are filled.

1. Latch open the separator blowdown valve (53), and turn the control switch (20) to RUN.
2. Close the separator blowdown valve (53) when the generator steam pressure gauge (49) registers 50 psi.
3. Open the separator blowdown valve several times for three to five second intervals during the first few minutes of operation.
4. Set the water by-pass regulator (38) to the required trainline pressure.

5. After the trainline is coupled open the stop and check valve (46). Open the remote control trainline shutoff valve (42) by depressing the latch and then open the manual trainline stop valve (43).

NOTES:

1. Check the return water flow after the steam generator has been operating long enough to have settled down to a steady output. On 4530 steam generators the return water flow indicator (35) should cycle from four to twelve times a minute. On 4516 steam generators the return water flow indicator should cycle from four to eight times a minute.
2. If the steam generator does not start or function properly, check all valves to see that they are correctly open or closed.
3. The steam generator should come up to full operating pressure in one or two minutes; it may take 10 or 15 minutes to build up the required operating steam pressure in the trainline.

RUNNING ATTENTION

1. Open the separator blowdown valve (53) for five seconds at least once every hour.
2. Turn the handle on the fuel filter during stops. At the same time, turn the handle on the filter for the water treatment injector where this method of water treatment is used.

TO SHUT DOWN THE STEAM GENERATOR

For short stops it is only necessary to close the stop and check valve (46). The fire will cycle and maintain operating pressure in the steam generator. For terminal stops, proceed as follows:

1. Close the stop and check valve (46), the remote control trainline shutoff valve (42) and the manual trainline stop valve.

2. Set the water by-pass regulator (38) at maximum output. When the generator steam pressure gauge registers 200 psi turn the control switch (20) to OFF.

3. Open the coil blowdown valve (17). When the generator pressure drops to 75 psi close the valve.

4. Open the separator blowdown valve (53) and blow down the steam separator (48) with the remaining pressure. Close the blowdown valve.

5. Open the fill-test valve (50) and turn the control switch (20) to FILL. When water discharges from the fill-test valve, turn the control switch to OFF and close the valve.

6. Close the atomizing air shutoff valve (1) and open the main switch.

NOTE: When starting again, drain the steam separator, open the fill-test valve, and fill the steam generator with water. If the coils are already full, it will only take a moment for water to discharge from the fill-test valve.

FREEZING WEATHER PRECAUTIONS

In severe weather, open the inlet valve to the radiation inside winterizing cabinets while the steam generator is in operation. During layovers, open the inlet valve whenever the temperature drops below freezing.

If a locomotive with a multiple installation does not have all of its steam generators in operation, open the coil blowdown valve (17) and the layover shutoff valve on idle steam generators, whether equipped with winterizing cabinets or not.

If a locomotive is left standing out of service, operate one of the steam generators or make a connection to the yard steam line. In extremely cold weather the water pump (29) and the generator controls should be given additional protection against freezing.

If no steam at all is available, thoroughly drain the steam generator. Open the drain valve (54) on the water treatment tank, the water pump test valve (30), the coil blowdown valve (17), the separator blowdown valve (53) and the coil shutoff valve (16). Break the pipe connections where necessary to completely drain the piping. Turn the water pump by hand to clear it of water, or blow it out with compressed air. Remove the cover of the water treatment or water strainer tank (34) and make sure it is drained.

TROUBLE SHOOTING

If one of the protective switches (magnetic overload relay or thermal overload switch, coil blowdown valve switch, stack switch high temperature contacts or low temperature outfire contacts) operates to shut down the steam generator the alarm will ring and the "boiler off" signal will flash on the engineer's control panel and engine control panel.

Turn the control switch (20) OFF and use the following instructions as a guide in locating the trouble.

MOTOR AND BURNER SHUT DOWN DURING OPERATION

1. Blown fuses or tripped circuit breakers: The alarm will not ring and instrument lights will go out. The circuit breaker or breakers are located on the control compartment panel and in some cases one is mounted in the main switch box near the steam generator. Check these breakers as well as the control fuses in the steam generator control cabinet.

2. Overload reset button "out". The alarm will ring, the instrument lights will remain on. Where a thermal overload switch is used, the reset button is located on the exterior of the control panel. Where a magnetic overload relay is used, the reset button is found inside the control cabinet on the relay itself. Turn the control switch (20) OFF: check for hot blower (11) or water pump (29) bearings and for

tight or loose pulley belts.

3. Stack switch reset button "out": The alarm will ring, the instrument lights will remain on; the high temperature contacts in the stack switch (5) are open. Turn the control switch (20) OFF; open the separator blowdown valve (53) and drain the steam separator (48). Close the separator blowdown valve, push in the stack switch reset button, refill the coils with water, and then start the steam generator.

4. Coil blowdown valve partially open: The alarm will ring, the instrument lights will remain on. Be sure the locking pin on the coil blowdown valve (17) handle is properly seated in the closed position.

MOTOR STARTS BUT BURNER DOES NOT

If the fire fails to light, the outfire contacts on the stack switch will not close, and after a 45 second time delay the outfire relay will open the circuit to shut down the steam generator. The alarm will ring and the instrument lights will remain on. Turn the control switch (20) OFF and check the following list for possible causes for the burner failure.

1. Ignition failure: No spark is visible through the peep hole glass. Check the ignition circuit fuses in the steam generator control cabinet. Tighten loose ignition cable connections and replace chafed or broken wire which may be breaking or grounding the ignition circuit.

2. Low atomizing air pressure: Low air pressure will fail to lift the diaphragm in the fuel spray head (7); the needle valve to the nozzle remains closed and prevents the admission of fuel to the firepot. Be sure the air admission valve is fully open. Clean the strainer screens at the air pressure reducing valve and in the air line.

3. Low fuel manifold pressure: Turn the handle on the suction line fuel filter (26) several times. A slight suction leak may cause the manifold pressure to build up slowly; put the control switch (20) on fill to bleed the fuel line and bring the manifold pressure up to normal.

4. Low fuel nozzle pressure: Lack of water causes the servo-fuel control (19) to limit the supply of fuel entering the nozzle. If the water supply is almost completely stopped, the servo may come down far enough to actuate the cutout switch and close the air solenoid valve (3) to shut off the atomizing air.

Be sure that the water pump test valve (30) is closed, that the water strainers (6) are clean, that the cover on the water treatment or strainer tank (34) is tight, that the three-way washout valve (55) is correctly positioned and that the drain valves (54) are tightly closed.

Free the water by-pass regulator (38) from possible sediment by opening and closing the adjusting handle. If this has no effect, close the water by-pass regulator shut-off valve (39); the feed water then flows directly to the servo-fuel control (19), and the steam generator will start at once if the by-pass regulator is at fault. Regulate the trainline pressure by adjusting the manual water by-pass valve (40).

High feed water temperature or leaky water line connections may cause the water pump (29) to become air or vapor bound. Violent fluctuation of the water pressure gauge (18) needle indicates this condition. Tighten leaky water line connections and bleed the line by opening the water pump test valve (30). Allow water to flow from this valve until no air or vapor bubbles are evident in the water.

IRREGULAR TRAINLINE PRESSURE

1. Burner cycles off and on: Insufficient water delivery causes the steam generator to run in superheat; the steam temperature limit control (23) operates to protect the coils against overheating. Check the water pump output as instructed in the preceding paragraphs.

2. Safety valves blow: Shut down the steam generator. Lower the trainline pressure setting on the adjusting handle of the water by-pass regulator (38) and start the generator again. If the safety valves (47) continue to pop, close the water by-pass regulator shut-off valve (39) and manually regulate the trainline steam pressure by opening and adjusting the manual water by-pass valve (40).

ITEMS TO REPORT

1. Water pressure greater than 450 psi at any time.
2. Excessive stack temperature.
3. Fluctuation of the fuel manifold gauge.
4. Frequent cycling of the burner off and on.
5. Water flow indicator not cycling.
6. Water by-pass regulator inoperative.
7. Improper function of the steam generator for any reason.

FICATION SYMBOLS

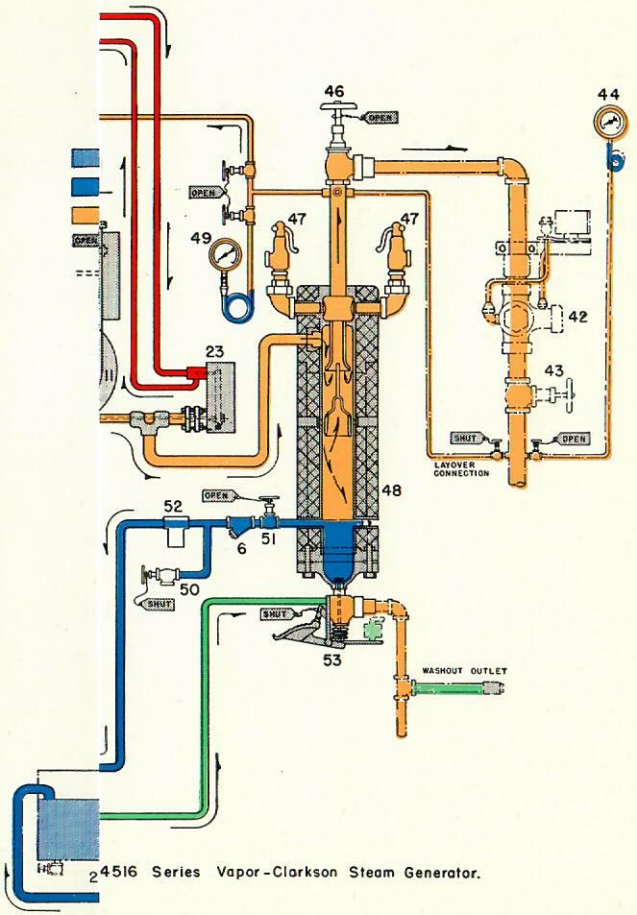
ontrol
h
l Pressure Gauge
essure line)
rature Limit Control
Regulator

action line)

Test Valve
re Relief Valve

Stop Valve
ent Tank (Strainer Tank
ent injector pump is used)
Flow Indicator

36—Heat Exchanger
38—Water By-Pass Regulator
39—Shutoff Valve, By-Pass Regulator
40—Manual Water By-Pass Valve
42—Remote Control Trainline Shutoff Valve
43—Manual Trainline Stop Valve
44—Trainline Steam Pressure Gauge
46—Stop and Check Valve
47—Safety Valves
48—Steam Separator
49—Generator Steam Pressure Gauge
50—Fill-Test Valve
51—Return Water Outlet Valve
52—Steam Trap
53—Steam Separator Blowdown Valve
54—Drain Valves
55—Three-Way Washout Valve
60—Ignition Transformer

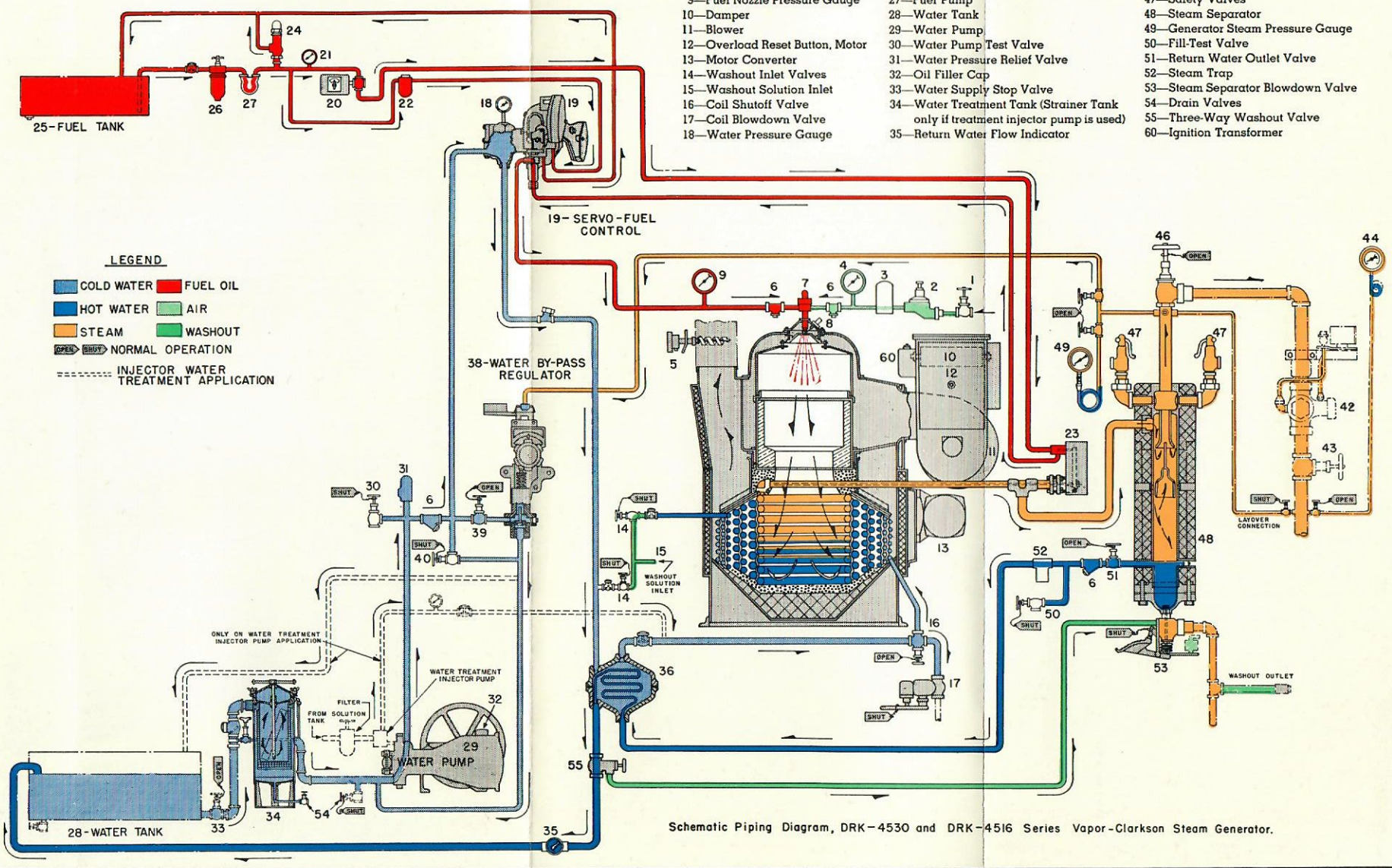


4516 Series Vapor-Clarkson Steam Generator.

VAPOR HEATING CORPORATION
RAILWAY EXCHANGE
CHICAGO 4

KEY TO IDENTIFICATION SYMBOLS

1—Atomizing Air Shutoff Valve
2—Air Pressure Reducing Valve
3—Air Solenoid Valve
4—Air Pressure Gauge
5—Stack Switch
6—Strainers
7—Fuel Spray Head
8—Spark Plugs
9—Fuel Nozzle Pressure Gauge
10—Damper
11—Blower
12—Overload Reset Button, Motor
13—Motor Converter
14—Washout Inlet Valves
15—Washout Solution Inlet
16—Coil Shutoff Valve
17—Coil Blowdown Valve
18—Water Pressure Gauge
19—Servo-Fuel Control
20—Control Switch
21—Fuel Manifold Pressure Gauge
22—Fuel Filter (pressure line)
23—Steam Temperature Limit Control
24—Fuel Pressure Regulator
25—Fuel Tank
26—Fuel Filter (suction line)
27—Fuel Pump
28—Water Tank
29—Water Pump
30—Water Pump Test Valve
31—Water Pressure Relief Valve
32—Oil Filler Cap
33—Water Supply Stop Valve
34—Water Treatment Tank (Strainer Tank only if treatment injector pump is used)
35—Return Water Flow Indicator
36—Heat Exchanger
38—Water By-Pass Regulator
39—Shutoff Valve, By-Pass Regulator
40—Manual Water By-Pass Valve
42—Remote Control Trainline Shutoff Valve
43—Manual Trainline Stop Valve
44—Trainline Steam Pressure Gauge
46—Stop and Check Valve
47—Safety Valves
48—Steam Separator
49—Generator Steam Pressure Gauge
50—Fill-Test Valve
51—Return Water Outlet Valve
52—Steam Trap
53—Steam Separator Blowdown Valve
54—Drain Valves
55—Three-Way Washout Valve
60—Ignition Transformer



Schematic Piping Diagram, DRK-4530 and DRK-4516 Series Vapor-Clarkson Steam Generator.

VAPOR-CLARKSON STEAM GENERATOR

CFK-4225-2B

DESCRIPTION OF CONSTRUCTION

The CFK-4225-2B Steam Generator can be in no way compared with a conventional boiler. There is no crown sheet, there are no fire tubes and no definite water level is maintained within the steam generator itself.

The complete steam generating unit comprises a coil type steam generator proper and a steam separator. The complete unit is equipped with all the necessary accessories and controls such as blower, heat exchanger, feed water pump, fuel pump, steam pressure limit control switches, stack switch, steam temperature limit control, fuel control, safety valves, stop valve, fuel and water solenoid valves, fuel and water relief valves, fuel filters, a rotary converter and transformer for ignition purposes, required blowdown valves, motor, main switch, ignition switch, steam generator control panel, etc.

The steam generator proper is essentially constructed of three sets of coiled water tubing connected in series to form a single tube several hundred feet in length. The coils are placed one within the other. The combustion chamber is formed and surrounded completely by the layers of the innermost coil. The coil construction is so arranged that a complete stagger is provided with free flow for gases which are split up into narrow films as they pass through the passages between the coil layers. The ends of the coils are so shaped than an effective seal is made to prevent by-passing hot gases. The coils are designed and arranged to allow for free expansion but are held in firmly stagger relation, with the flow of water through the coils opposite to that of the fire gases to ensure maximum heat transfer. The coils are wound with super-imposed layers, there being two layers for each coil. Two soot blowers are provided in the flue passage between the outer coil and the steam generator

frame for blowing the soot off the coils periodically. The soot blowers are connected to the Steam Separator to allow steam to be used for soot blowing when the valves installed in the line are opened for this purpose.

The burner is of the down-draft, air pressure atomizing type and includes a Fuel Spray Head, a Fuel Solenoid Valve mounted at top of Spray Head for electrically controlling the admission of fuel and Spark Plugs for the electric ignition of the fuel.

BRIEF DESCRIPTION OF THE FUNCTION OF CONTROLS AND OTHER APPURTENANCES

Air Pressure Reducing Valve — Regulates the pressure of the air for air atomization (breaking up into a fine mist) of the fuel.

Alarm Panel — Gives an alarm by ringing a bell in case of any steam generator failure.

Atomizing Air Control Switch — Prevents or stops the flow of fuel to the burner in the event there is no atomizing air pressure or the air pressure is too low.

Blower — Delivers air to the burner for combustion of the fuel.

Coil Blowdown Valve — Manually operated valve for blowing sediment out of the steam generating coils. This valve should not be used while steam generator is operating.

Coil Blowdown Valve Switch — Prevents the steam generator from operating when the Coil Blowdown Valve is open.

Control Panel — Contains the required relays for automatic control of the steam generator as well as a Motor Overload Protection Switch.

Fuel Control — Proportions the flow of fuel to the burner to the amount of water pumped into the steam generating coils for evaporation into steam. Also, shuts down the burner automatically preventing the flow of fuel to the Fuel Spray Head in the absence of water supply.

Fuel Control Manifold — Houses the Fuel Key Metering Valve, the Manual Fuel By-Pass Valve and the Fuel Oil Relief Valve.

Fuel Key Metering Valve — Used for trimming the amount and the pressure of the fuel allowed to pass to the burner to obtain clear stack gases. By-passes a portion of the fuel delivery back to the supply tank.

Fuel Oil Filter — Filters the fuel oil in the fuel suction line.

Pressure Fuel Oil Filter — Filters the fuel oil in the fuel pressure line.

Fuel Pump — Delivers fuel oil to the burner for combustion.

Fuel Solenoid Valve — Provided for the purpose of electrically controlling the flow of fuel to Fuel Spray Head (Burner).

Fuel Spray Head — Equipped with a spray nozzle. Sprays fuel oil into the fire pot and combustion chamber.

Heat Exchanger — Preheats the feed water to the steam generator after the burner has been started by recover of heat from the return water.

Ignition Switch — Switches on the ignition by starting the Rotary Converter. Also, protects the Rotary Converter against electrical overloads. In event of overload this switch will open and will shut down the Converter.

Main Switch — When closed makes current available for the starting and automatic operation of the steam generator.

Manual Fuel By-Pass Valve — When open, shuts off the flow of fuel to the burner by by-passing all fuel back to the supply tank.

Motor — Drives the water pump, the fuel pump which is mounted thereon and geared thereto, and the blower.

Motor Overload Reset Switch — Protects the motor against continued overloads. The reset button will come out opening the circuit if the motor is overloaded.

Operating Switch — Sets the steam generator to Off, Test, Start or Run position.

Resistor Cabinet — Contains the resistors required for automatically accelerating and decreasing the speed of the motor in accordance with the range selected and the Main Steam Pressure Switch operation.

Rotary Converter — Converts direct current input into alternating current output for transformer ignition.

Safety Valves — Two provided. One set to release at 245 pounds; the other at 250 psi steam pressure.

Spark Plugs — Give a continuous electric spark for the ignition of the fuel.

Stack Switch — This is a safety device with a helix extending into the stack for the purpose of shutting down the steam generator if the temperature of the stack gases becomes too high (reaches 900° F). This device also closes the Fuel Solenoid Valve and shuts down the motor in conjunction with an Outfire Relay should the fire fail to light within 45 seconds.

Steam Pressure Switch, Main — Controls the steam pressure and the amount of steam generated in accordance with the pressure setting, the operating range selected and the steam demand, by varying the speed of the motor. Works in conjunction with load relays on the control panel to vary the speed of the motor in five (5) different positions, by cutting in or cutting out varying sections of resistance on the Resistor Cabinet.

Steam Pressure Switch, Secondary — Operates in conjunction with the Main Steam Pressure Switch when set to "Freight" Operation to shut down the burner at about 150 pounds pressure or whatever the pressure setting of the Main Pressure Switch may be and to recycle the fire back "on" at about 50 or 75 pounds pressure, the usual setting of the Secondary Pressure Switch.

Steam Separator — Separates the excess water from the steam for return to the tank and centrifugally removes the solids from the steam into a mud sump for periodical blowing out purposes.

Steam Separator Blowdown Valve — This is a foot operated valve. The solids and mud that deposit in the sump of the Separator are blown out by opening this valve while the steam generator is under pressure.

Steam Temperature Limit Control — This control prevents excessive steam temperature by preventing the flow of fuel to the burner to cause the fire to shut down when the maximum steam temperature limit setting of this control is reached — 425° F.

Steam Trap — Discharges excess water from the Steam Separator for return to the Tank.

Stop Valve — Feeds steam to the steam trainline and is used for regulating the trainline steam pressures.

Switch Box — Contains the Operating Switch, a pilot relay and an outfire relay.

Transformer — Steps up the alternating current from the Rotary Converter to 10,000 volts for ignition purposes.

Try-Cocks — Provided for checking the return water level in the Steam Separator. These cocks do not indicate level of water in the steam generator, but merely indicate height of water separated out of the steam in the Steam Separator.

Water By-Pass Solenoid Valve — By-passes the water pump water delivery back to the storage tank whenever the fire in the burner is shut down by the operation of the Main Pressure Switch due to reaching of the steam pressure limit setting. Opened electrically.

Water Gauge Glass — Shows height of water level in Steam Separator.

Water Pump — Delivers water to the steam generator for evaporation into steam.

Water Relief Valve — Protects the water pump against over-pressure should the Coil Shutoff valve be left closed unintentionally or should there be a stoppage in the line.

Water Treatment Tank — A container for treating the feed water by dissolving water treating compound in stick form only.

DESCRIPTION OF OPERATION

GENERAL

There are six (6) systems involved in the operation of the steam generator, namely; the fuel system, atomizing air system, ignition system, combustion system, water system and control system.

a. The Fuel System supplies fuel to the burner for combustion.

b. The Atomizing Air System breaks up the fuel oil into a fine mist for good combustion and prevents the flow of fuel to the burner in the event the atomizing air pressure is insufficient for proper combustion of the fuel.

c. The Ignition System provides automatic electric ignition of the fuel.

d. The Combustion System provides a forced draft of air in proper ratio to the fuel supply for combustion of the fuel.

e. The Water System supplies water for evaporation into steam and includes means for control of the feed water in proportion to the fuel feed.

f. The Control System includes electrical equipment for starting and stopping of the steam generator and for the automatic control of steam pressure as well as steam output in accordance with demand. This system also includes mechanical and electrical controls for proportioning the fuel delivery to the water delivery, for cutting off the fuel delivery in case of ignition failure and for shutting down the steam generator should the temperature of the steam and stack gases become excessive.

DIRECTIONS FOR OPERATING

PREPARATIONS FOR STARTING

1. See That The Following Valves Are OPEN:

   Water Suction Stop Valve
   Coil Shutoff Valve
   Water Return Valve
   Steam Trap Shutoff Valve

2. See That The Following Valves Are CLOSED:

   Drain Valve in Water Suction line between water Treatment Tank and Water Pump
   Coil Blowdown Valve
   Solution Admission Valve
   Solution Return Valve
   Water Pump Test Valve
   Water Strainer Blow-off (Clean-out) Valve

3. See that Water Treatment Tank Cover is on tight, cross bolt must be screwed down tight.

4. See that the Steam Gauge Shutoff Cock and Pressure Switch Shutoff Cock are open.

5. See that the Reset Button on Control Panel is "In".

6. See that Stack Switch Reset Button is "In".

7. See that the Manual Fuel By-Pass Valve is closed.

8. See that Main Steam Pressure Switch is set to the maximum steam generator pressure desired, preferably not less than 150 pounds.

TO START

1. Close Main Switch.

2. Close Ignition Switch.

3. Set the toggle switch on the Secondary Steam Pressure Switch to "Passenger" or "Freight" position as required, depending upon whether the steam generator is in passenger train or freight train service.

3. Fill Steam Generator Coils With Water, as follows:

   a. Open Separator Blowdown Valve to drain Steam Separator. (This valve is foot operated).

   b. When water disappears in Water Gauge Glass, close Separator Blowdown Valve.

   c. Turn Operating Switch to "Test" position.

   d. When water rises to about the middle of the Gauge Glass, open Separator Blowdown Valve.

   e. Turn Operating Switch to "Off".

NOTE: During the time the steam generator is being filled with water, check to see that spark is available by looking through Sight Glass at top of steam generator.

5. Open the Atomizing Air Admission Valve and check the air pressure on gauge which should be between 20 and 23 pounds.

6. Turn Operating Switch to "Start". Fire should start immediately.

7. After fire has operated for 2 or 3 minutes, close Separator Blowdown Valve.

8. "Crack" Trainline Stop Valve slightly and open gradually to maintain desired steam generator pressure on the Steam Pressure Gauge.

9. To obtain proper trainline steam pressure, throttle with Stop Valve. Steam generator (Boiler) pressure should be higher than trainline pressure.

10. Turn Operating Switch to "Run" position to charge trainline, then return to "Start" and allow steam generator to operate in this position if it will maintain the required steam pressure. If not, turn switch to "Run".

11. It may be necessary to set up the Main Steam Pressure Switch setting in order to obtain proper trainline pressure.

NOTES:

1. It may take 5 to 10 minutes time to fill the steam generator with water if empty.

2. It may take 10 to 15 minutes time to build up proper trainline steam pressure when all the radiators are open.

3. The Fuel Key Metering Valve is opened about one-half of a turn. This valve is set to trim the fuel pressure to obtain a clean fire and a clear track.

4. After starting the steam generator and before leaving the terminal, the Operator or Fireman must inspect the following blowdown pipe and drain pipe openings for leaks:

Separator Blowdown, Coil Blowdown, Water Treater Drain. If leaking see that valves are closed tight. Proper measures must be taken to stop leakage if due to any other cause.

NEVER START STEAM GENERATOR UNLESS YOU ARE SURE THAT THE COILS HAVE BEEN FILLED WITH WATER. WATER LEVEL IN STEAM SEPARATOR GAUGE GLASS DOES NOT INDICATE THAT STEAM GENERATOR COILS ARE FILLED WITH WATER.

RUNNING ATTENTION

AT START OF EACH TRIP AND DAILY THEREAFTER:

1. Open Water Gauge Glass Blowdown Valve for about 2 seconds to blow down the gauge glass.

2. Open Steam Trap Strainer Blowoff Valve for about 2 seconds.

3. Pull Safety Valve levers while under steam to ensure that the Safety Valves are free.

HOURLY:

1. Use Soot Blower Valves: To use Soot Blower Valves proceed as follows:

   a. See that the steam is at 150 pounds pressure or more. (Set up Main Pressure Switch and throttle with Stop Valve if necessary).

   b. Open Steam Admission Valve to Soot Blower Valves.

   c. Alternately pull each Soot Blower Valve for several 3 second intervals.

d. Close Steam Admission Valve.

e. Pull Soot Blower Valves again to drain Soot Blower lines.

2. Open the Separator Blowdown Valve for about 2 seconds to blow down the Steam Separator. (This valve is foot operated).

3. Turn handle on Fuel Filter one full turn clockwise.

PERIODICALLY DURING COURSE OF TRIP:

1. Check water level on Steam Separator Water Gauge Glass. The water level should be at or slightly above the center of the glass.

2. Check the feed water temperature at the Steam Generator Feed Check Valve which should be warm. If too hot, this is because of insufficient fuel which may be caused by a dirty fuel strainer or a dirty fuel spray head nozzle. The water level may be excessive. If fuel line is O.K. and the nozzle as well as the fuel strainer are clean, increase the fuel pressure with the Key Metering Valve to burn more fuel. If check valve is too cold, burn less fuel by decreasing the fuel pressure.

3. Check the water pump operation on Water Pressure Gauge. The pressure should not be over 400 pounds if the steam generator coils are clean. The gauge should be steady; jumping action indicates faulty pump action or air leak in water suction line. If feed water is too hot, water pump valves may become vapor bound, also giving jumping action to water gauge. Vapor bound valves or air in suction line can be corrected by opening the Air Bleeder Valves on the Water Pump Suction Valve Caps.

4. Empty drip pan under Water Pump packings as required. A slight leakage is normal; it keeps the packing lubricated.

5. Check level in water tanks.

TO STOP

For Short Stops: (15 minutes or less)

1. Close Trainline Stop Valve. This is all that is necessary. (The fire will cycle "on" and "off" to maintain pressure on the steam generator).

For Terminal Stops: (End of Trip).

1. Close Trainline Stop Valve.

2. Set up the Main Steam Pressure Switch to 200 psi pressure.

3. Use the Soot Blower Valves as hereunder indicated:

   a. Open Steam Admission Valve to Soot Blower Valves.

   b. Alternately pull each Soot Blower Valve for several 3 second intervals.

   c. Close Steam Admission Valve.

   d. Pull Soot Blower Valves again to drain soot blower lines.

4. At 200 psi steam pressure turn Operating Switch to "Off".

5. Open Coil Blowdown Valve. (Knob on Coil Blowdown Valve must be pulled outwards to release handle for opening the valve).

6. Return Steam Pressure Switch to normal.

7. Close Atomizing Air Admission Valve.

8. Turn Ignition Switch to "Off".

9. When the steam pressure drops to 100 psi, close Coil Blowdown Valve.

10. Open Separator Blowdown Valve to blow down the Steam Separator with the remaining pressure.

11. Close Separator Blowdown Valve when all pressure is gone.

12. Turn Operating Switch to "Start" position. The low fire contacts on the Stack Switch should shut down the motor in about 90 to 120 seconds. (Where Photo-Electric Control is used instead, it will shut down the motor in about 20 seconds). This is a test for the operation of these devices.

13. Turn Operating Switch to "Test" position to fill steam generator coils with water.

14. When water level in Water Gauge Glass rises to about the height of the bottom Try-Cock, turn operating Switch to "Off" position.

15. Open Main Switch

THE STEAM GENERATOR IS NOW FILLED AND READY FOR USE. ALWAYS LEAVE STEAM GENERATOR THIS WAY.

NOTE: In extreme cold weather enroute, when locomotives are equipped with more than one Steam Generator and only one Steam Generator is operated, precautions must be taken to prevent freeze-up of the other Steam Generator(s).

GENERAL OPERATING INFORMATION AND SERVICE INSTRUCTIONS

CAUSES OF STEAM GENERATOR SHUT DOWN

ALARM BELL DOES NOT RING

1. If light is "on" on Steam Generator Gauge Panel, shut down is due to reaching of Steam Pressure Switch setting. Steam Generator will restart automatically when steam pressure has dropped sufficiently below Pressure Switch Setting.

2. If light is "out" on Steam Generator Gauge Panel, shut down is due to blowing of fuse in Battery Control Panel.

ALARM BELL RINGS IN "START" AND "RUN" POSITIONS

1. Reset Button out on Stack Switch. Shut down due to excessive stack temperature.

   Proceed as follows:

   a. Turn Operating Switch to "Off".

   b. Close Stop Valve.

   c. Open Separator Blowdown Valve to drain Steam Separator and reclose valve.

   d. Turn Operating Switch to "Test" to refill steam generator with water. This will allow blower to cool down the stack.

   e. Reset Stack Switch Button.

   f. Restart Steam Generator.

g. Blow the soot off the coils by using the Soot Blower Valve with the steam at about 200 psi pressure. Raise Pressure Switch setting, if necessary.

h. When normal conditions are restored, open Stop Valve.

i. If Stack Switch button keeps coming out, lower the fuel pressure with the Key Metering Valve to keep down the stack temperature.

NOTE: Insufficient water delivery brought about by failure of one of the water pump valves or by restriction of Water Treatment Tank strainer due to dirt may be responsible for high stack temperature.

ALARM BELL RINGS IN ANY POSITION OF OPERATING SWITCH

1. Reset Button out on Control Panel. Shut down due to Motor Overload.

   Proceed as follows:

   a. Open Main Switch to stop ringing of alarm.

   b. Close Stop Valve.

   c. Wait about four (4) minutes to allow thermal element on Overload Reset Switch to solidify. While waiting, check for cause of overload.

   d. Reset Motor Overload Switch Button.

   e. Close Main Switch.

   f. Reset Operating Switch to "Off" before attempting to restart steam generator.

   g. When normal conditions are restored, open Stop Valve.

2. Fuse Blown On Steam Generator Control Panel.

   a. Pull Main Switch; replace fuse.

   b. Close Main Switch and restart steam generator.

ALARM BELL RINGS AND ALL RESET BUTTONS "IN"

1. Shut Down Due To Outfire Relay Operation — Indicated by restarting of motor when Operating Switch is turned to "Off" and then back to original position.

   A. No Ignition — No Spark at Spark Plug Electrodes. Shut down may be due to overload in Rotary Converter circuit.

      Proceed as follows:

      a. Wait 2 minutes to allow heater element on Ignition Switch to cool. The switch trips free from the handle and cannot be held "On" against overload. Check for cause of overload during this period.

      b. Return Ignition Switch handle to "Off" position and then turn back to "On".

      c. Reset Operating Switch to "Off" position before attempting to restart steam generator.

   B. Atomizing Air Pressure Insufficient (less than 15 pounds). Shut down due to operation of Atomizing Air Switch.

      a. See that Air Admission Valve is fully open.

b. Strainer at Air Pressure Reducing Valve inlet probably clogged and should be cleaned.

c. Internal parts of Air Pressure Reducing Valve may be gummed up and require cleaning.

NOTE: Reset Operating Switch to "Off" before attempting to restart steam generator.

C. Lack Of Water Is Indicated by absence of water discharge or insufficient water discharge from Water Pump Test Valve and low water pressure when valve is opened and motor is restarted.

a. After correcting difficulty, reset Operating Switch to "Off" before attempting to restart steam generator.

D. Shut Down To Lack Of Fuel will be indicated by low fuel pressure and by discharge of water from Water Pump Test Valve when valve is opened and motor is restarted.

a. Fuel may be shut off by the Steam Temperature Limit control because of excessive steam temperature due to excessive fuel or insufficient water delivery.

b. After correcting difficulty, reset Operating Switch to "Off" before attempting to restart steam generator.

2. Coil Blowdown Valve Open or Coil Blowdown Valve Switch not contacting.

TROUBLE SHOOTING

(This Trouble Shooting Guide is intended for both Operators and Maintainers. Any difficulties that may be encountered enroute by the Operator, however, will generally be due to the opening or closing of wrong valves or to improper setting of Fuel Key Metering Valve).

MOTOR FAILS TO START

1. Main Switch open. (Gauge Panel lights will be out).
2. Coil Blowdown Valve open or Coil Blowdown Valve Switch not contacting.
3. Stack Switch Reset Button out.
4. Reset button out on Steam Generator Control Panel.
5. Low Voltage.
6. Current not available to motor.
   a. Fuse blown on Steam Generator Control Panel.
   b. Boiler Positive or Negative Switch may be tripped on Control Compartment Panel in cab. (Gauge Panel lights out).
   c. Relay contacts not making contact.
   d. Breaks in wiring or leaks to ground.
7. Check motor:
   a. Brush contact may be improper.
   b. Brushes or brush mechanism may be faulty.
   c. Motor coil may be grounded.
   d. Leak to ground.
   e. Dirt or high mica between segments in armature.

MOTOR RUNS IN "TEST" POSITION BUT NOT IN "START" OR "RUN" POSITION

1. Stack Switch Reset Button Out.
2. Coil Blowdown Valve Open.
3. Coil Blowdown Valve Switch not contacting.
4. Outfire relay de-energized through low temperature range contacts on Stack Switch because of insufficient air pressure, ignition failure, lack of fuel or lack of water.

FIRE FAILS TO START AND MOTOR SHUTS DOWN

INSUFFICIENT AIR PRESSURE FOR ATOMIZATION OF FUEL:

1. Air Admission Valve closed. This valve must be fully open.
2. Air Pressure Reducing Valve not adjusted for a minimum of 20 pounds pressure.
3. Strainer at Air Pressure Reducing Valve inlet clogged.
4. Internal parts of Air Pressure Reducing Valve may be gummed up by accumulation of dirt or deposit. Unscrew bottom cap to get at the internal parts.

IGNITION FAILURE:

1. No Spark At Spark Plug Electrodes
   a. Ignition Starting Switch In "Off" position.
   b. Ignition Switch mechanism tripped open by heater element because of overload in Rotary Converter Circuit. Allow 2 minutes for heater element to cool then return switch to "Off" and then turn to "On".

2. Spark Plugs
   a. Spark Plug electrode gap improper.
   b. Electrodes not located properly to ignite fuel spray.
   c. Electrodes grounded.
      1. Dirty or damaged insulator.
      2. Spark Plug shorting to centralizing cone or to burner housing cover.
      3. Carbon on electrodes. (Caused by flame burning too close to nozzle due to improper positioning of electrodes.)
3. Ignition Cable And Connections
   a. Chafed or broken.
   b. Loose cable connection.
4. Spark Available, Fuel Spraying From Nozzle But No Fire.
   a. Water in oil.
   b. Air Atomizing Pressure too low.
   c. Obstruction in Fuel Spray Head Nozzle.
   d. Improper angle of fuel spray cone.
   e. Damaged fuel spray nozzle.
   f. Too much air.

LACK OF FUEL:

1. Flow Of Fuel Oil To Spray Head Restricted Or Stopped.
   a. Manual Fuel By-Pass Valve open. This valve must be shut.
   b. Fuel Key Metering Valve fully open. This valve must be open only about one-half of a turn.
   c. Dirty strainer screen at Fuel Spray Head.
   d. Fuel Spray Nozzle clogged.
   e. Fuel line kinked or leaking.
   f. Diaphragm in Fuel Control Ruptured or torn.
   g. Fuel solenoid valve coil burned out.
2. Fuel Suction Failure
   a. Air leak in suction line or fittings. See that all connections are tight.
   b. Pump shaft packing faulty. Tighten or repack.
   c. Suction line valve restricted.
   d. Faulty fuel pump drive.

LACK OF WATER:

1. Lack of water supply.
2. Water Suction Stop Valve closed.
3. Drain Valve open between Water Treater and Water Pump.
4. Water Pump Test Valve Open.
5. Water Treater Cover loose.

6. Water Treater Screen clogged up.
7. Air in water suction line. (See that all connections are tight. After air leak has been repaired air in water suction line can be removed by opening the Water Pump Test Valve).
8. Coil Blowdown Valve leaking.

NOTE: The Operating Switch must be reset to "Off" position before the steam generator can be re-started in the regular manner if shut down during operation due to failure of fire to start.

FIRE AND MOTOR SHUT DOWN DURING OPERATION

EXCESSIVE STEAM TEMPERATURE (Excessive steam temperature may cause the fire to cycle "Off" and "On". Steam Generator may not come up to pressure).

1. Insufficient Water Delivery.
   a. Check water supply.
   b. Check for air in water suction line. See that all connections are tight.
   c. Check for dirt between water pump valves and seats. A water pump valve may be defective.
   d. Coil Shutoff Valve not fully open.
   e. Water Treater Cover loose.
   f. Water Suction Stop Valve, Drain Valves and Water Pump Test Valve not fully shut.
   g. Water Treater screen clogged.
   h. Vapor binding in water pump caused by excessive feed water temperature.

i. Belts slipping.

j. Coil Blowdown Valve leaking.

k. Leaks in Coil Nipples or in Steam Generating Coils.

l. Leak in Heat Exchanger.

2. Excessive Fuel

a. Lower fuel pressure with Fuel Key Metering Valve.

NOTE: When cause of excessive steam temperature has been corrected it will be necessary to open Steam Separator Blowdown Valve for about two seconds to drain Steam Separator and to refill the steam generator with water.

EXCESSIVE STACK TEMPERATURE (Reset Button out on Stack Switch):

1. Steam Generator Coils Sooted Up.

a. Open Separator Blowdown Valve for about 2 seconds to drain Steam Separator and refill the steam generator with water to allow the blower to cool down the stack. Reset Stack Switch and restart steam generator. Pull Soot Blower Valves several times after opening Steam Admission Valve to Soot Blower Valves. If this does not help much to keep reset button "In" reduce the fuel pressure enroute to keep the stack switch reset button "In". Soot may have to be scraped off manually by maintainer.

2. Insufficient Water Delivery due to failure of one of the water pump valves or a restriction in the line may also cause excessive stack temperature.

MOTOR OVERLOADED
(Reset Button Out on Control Panel):

1. Electrical circuit overloaded or short circuited.

2. Tight motor bearings. Lubricate bearings.

3. Tight water pump bearings. Lubricate bearings.

4. Tight blower fan. Lubricate bearings.

NOTE: Wait for about 4 minutes to allow thermal element on Motor overload Reset Switch to solidify before resetting. Correct cause of overload in the meantime if due to other cause than temporary overload in the motor circuit.

FIRE AVAILABLE BUT OPERATION OF STEAM GENERATOR NOT SATISFACTORY

BURNER HAS DELAYED STARTING BUT OTHERWISE FIRE IS SATISFACTORY:

1. Carbon on spark plug electrodes.

2. Spark plug electrodes shorting.

3. Improperly adjusted and positioned spark plug electrodes.

4. Restricted fuel line resulting in too much air supplied for the amount of fuel delivered.

a. Dirty strainer at Fuel Spray Head.

b. Dirty fuel spray nozzle.

c. Faulty nozzle. Replace if found defective on examination.

d. Fuel Key Metering Valve gummed up.

e. Fuel Control Valve binding or gummed up. Free by cleaning valve and seat.

f. Fuel Suction Valve restricted.

g. Kink or other restriction in the fuel line.

h. Air in fuel suction line.

i. Leak in fuel feed line.

j. Fuel pump defective or worn. Wear will increase the tolerances and decrease the capacity of this pump.

5. Improper adjustment of air dampers.

6. Water in fuel or poor grade of fuel.

SMOKY STACK

1. Improper fuel pressure. Adjust with Key Metering Valve.

2. Improper air Readjust Blower Air Dampers.

3. Partly clogged or damaged fuel spray nozzle.

INSUFFICIENT STEAM OUTPUT (Steam Pressure fails to build up):

1. Check for steam leaks or wastage.

2. Insufficient water. (Fire may be cycling "Off" and "On" because of excessive steam temperature).

3. Insufficient fuel.

4. Belts slipping.

5. Motor not operating at proper speed.

a. Low voltage.

EXCESSIVE CYCLING OF FIRE "ON" AND "OFF"

1. Turn Operating Switch from "Run" to "Start" position to lower steam output.

2. Where steam demand is very light, steam generator can be shut down for a period of time and then restarted. Preferable switch to "Freight" position on Secondary Pressure Switch.

WATER RELIEF VALVE UNLOADING WATER:

1. Closed Coil Shutoff Valve.

2. Plugged Heat Exchanger.

3. Feed line from pump to coils plugged.

4. Steam Generator coils scaled up and require washing.

WATER LEVEL TOO HIGH:

1. Insufficient fuel.

2. Water Return Line Valve before Steam Trap closed or restricted.

3. Water Return Valve closed or restricted.

4. Clogged water return line.

5. Steam Trap failure.

WATER LEVEL TOO LOW: (May be due to Excessive Steam Temperature):

1. Excessive Fuel.

2. Insufficient Water.

3. Leaking Coil Blowdown Valve.

FEED WATER CHECK VALVE TOO HOT (Excessive Water Return when Steam Generator is Running Steadily): (Indication of Excessive Feed Water Temperature).

1. Insufficient Fuel.
   a. Dirty Fuel Strainer Screen at Fuel Spray Head.
   b. Fuel Spray Nozzle orifices clogged.
   c. Manual Fuel By-Pass Valve not fully closed.
   d. Fuel Key Metering Valve requires readjustment.
2. Steam Trap Defective (Blowing line steam to Heat Exchanger).

FEED WATER CHECK VALVE TOO COLD (Insufficient Water Return):
(Indication of Excessive Steam Temperature).

1. Insufficient Water Delivery.
2. Excessive Fuel.
3. Coil Blowdown Valve leaking.
4. Water return line from Steam Separator may be plugged.
5. Steam Trap plugged with dirt or trap valve port restricted by scale and dirt.

STEAM TRAP FAILURE:

1. No Discharge from Trap. High Water Level in Steam Separator.
   a. Return Water Shutoff Valves closed.
   b. Return Water Line to trap or elbows plugged up with dirt.
   c. Bucket Vent plugged.

   d. Trap body filled with dirt.
   e. Bucket trap valve port restricted.
   f. Worn or defective trap mechanism. Examination will show which parts are worn or may otherwise require replacement.
2. Steam Loss. Trap blows live steam to Heat Exchanger.
   a. Trouble may be due to failure of valve in trap to seat, caused by scale or pipe cutting lodging in orifice, worn seat or loss of prime.

EXCESSIVE WATER PRESSURE (Over 450 pounds or 100 pounds above normal)

1. This is an indication that the steam generating coils are scaling up and should be washed out by the maintenance force.

VIOLENT MOVEMENT OF WATER PRESSURE GAUGE HAND:

1. Air locked cylinder.
2. Leaky water pump valve. Valves may need regrinding.
3. Vapor bound pump valve if feed water is too hot.
   a. Clear cylinders of air or vapor by opening Air Bleeder Valves (Suction Test Plugs) and check for cause of excessive water temperature.

METHOD OF CHECKING FOR LEAKS IN STEAM GENERATING COILS AND IN HEAT EXCHANGER

(Excessive steam temperature may be due to a leak or leaks in the steam generating coils and in the coil of the Heat Exchanger).

LEAK IN STEAM GENERATING COILS will be indicated visually by the presence of water or the blowing of steam on the inside of the steam generator upon the removal of the side plates.

TO CHECK FOR LEAK IN HEAT EXCHANGER

Proceed as follows:

1. Remove the feed water return lines at Heat Exchanger.
2. Start Water Pump in "Test" position of Operating Switch.
3. Slowly close Coil Shutoff Valve and check water pressure so as not to exceed 500 pounds hydrostatic pressure.
4. If Water Comes out of either of the two openings (return water inlet and outlet) on the Heat Exchanger the Heat Exchanger Coil is leaking. The Heat Exchanger Coil should be replaced or an entirely new Heat Exchanger should be substituted.

NOTE:

A leaky Heat Exchanger may allow the steam generator to go into superheat or will cause the steam output to be reduced. This will be due to insufficient water due to leaking of feed water through the Heat Exchanger back to the supply tank.

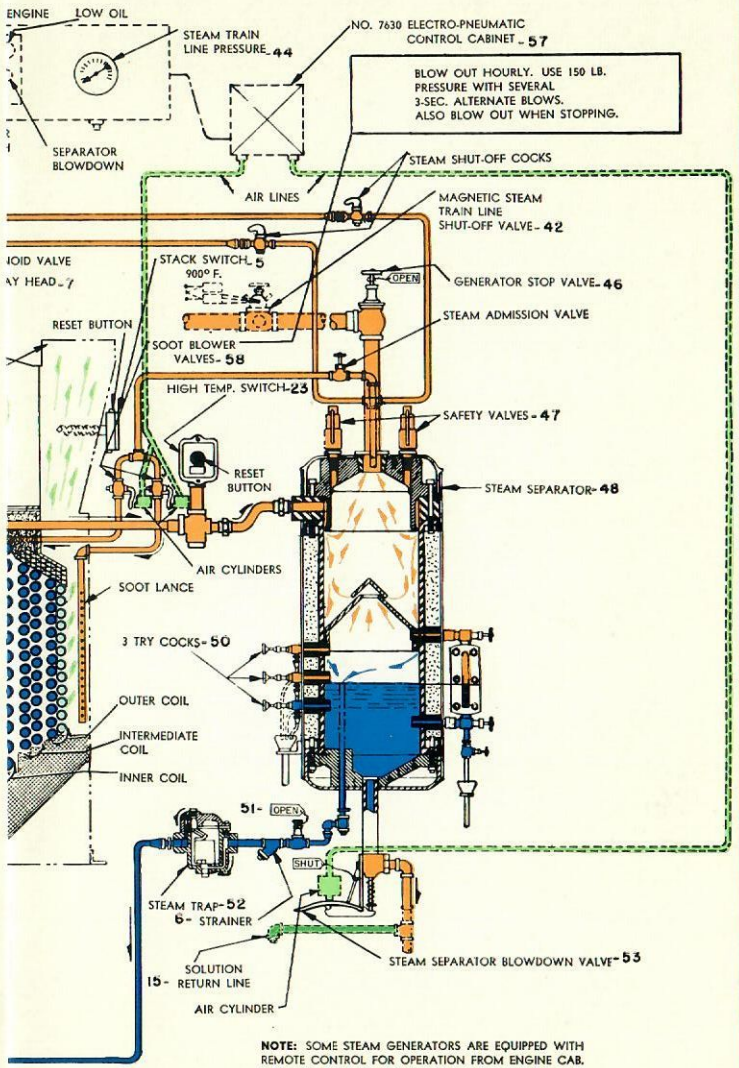
ELECTRICAL CONTROL DATA

S THE FIVE SPEEDS OF THE MOTOR.
TION OF BOILER IN CASE COIL BLOW-
O LOW AIR PRESSURE.

*STACK SWITCH—SHUTS OFF MOTOR AND OPERATES ALARM BELL WHEN STACK GAS REACHES TOO HIGH A TEMPERATURE. ALSO SHUTS DOWN THE MOTOR IN THE EVENT OF IGNITION FAILURE.

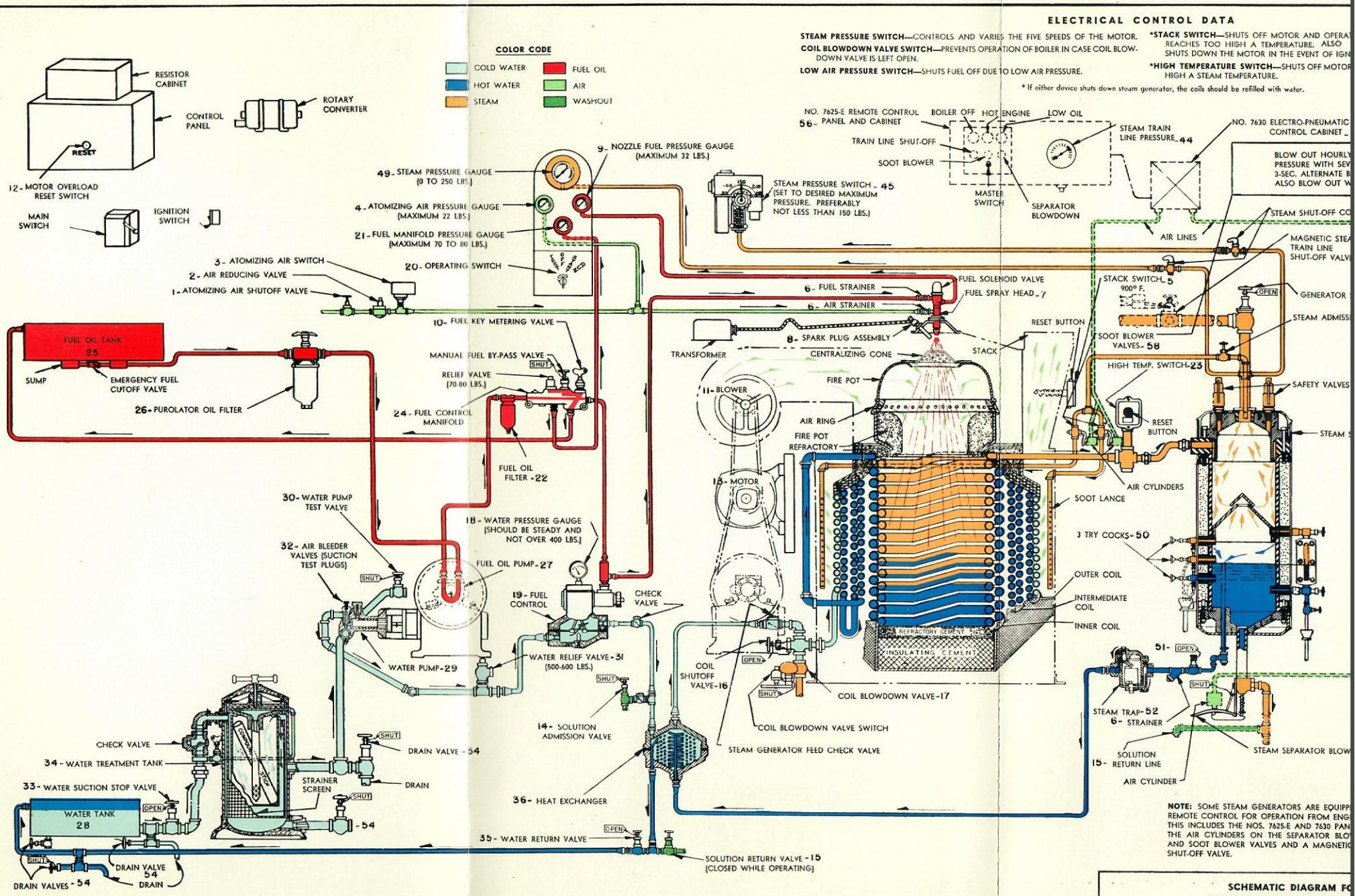
*HIGH TEMPERATURE SWITCH—SHUTS OFF MOTOR AND OPERATES ALARM BELL AT TOO HIGH A STEAM TEMPERATURE.

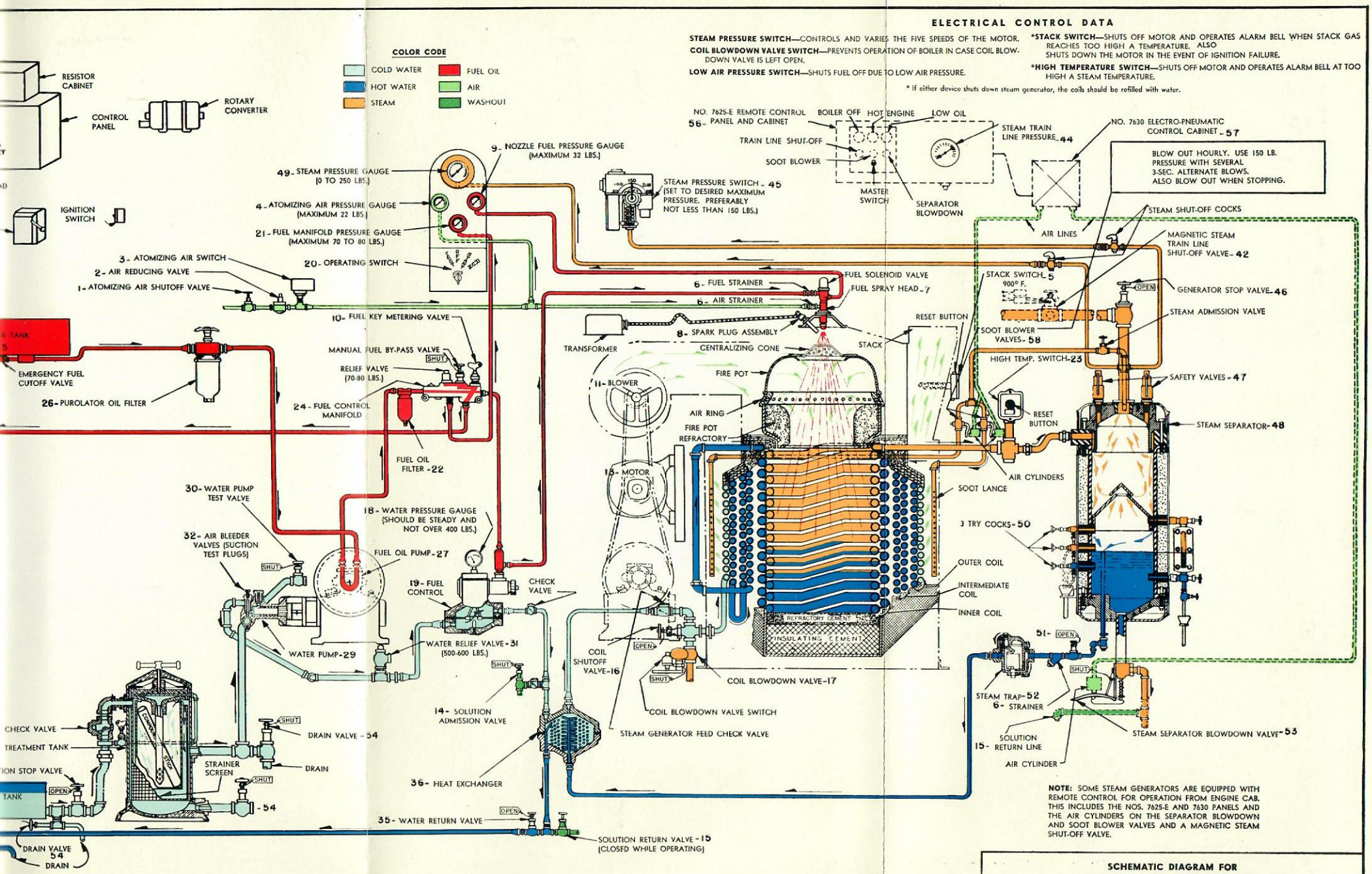
* If either device shuts down steam generator, the coils should be refilled with water.



NOTE: SOME STEAM GENERATORS ARE EQUIPPED WITH REMOTE CONTROL FOR OPERATION FROM ENGINE CAB. THIS INCLUDES THE NOS. 7625-E AND 7630 PANELS AND THE AIR CYLINDERS ON THE SEPARATOR BLOWDOWN AND SOOT BLOWER VALVES AND A MAGNETIC STEAM SHUT-OFF VALVE.

SCHEMATIC DIAGRAM FOR CFK-4225-2A AND CFK-4225-3A TYPE VAPOR-CLARKSON STEAM GENERATING UNITS


COLOR CODE
COLD WATER
HOT WATER
STEAM
FUEL OIL
AIR
WASHOUT
ELECTRICAL CONTROL DATA
STEAM PRESSURE SWITCH—CONTROLS AND VARIES THE FIVE SPEEDS OF THE MOTOR.
COIL BLOWDOWN VALVE SWITCH—PREVENTS OPERATION OF BOILER IN CASE COIL BLOWDOWN VALVE IS LEFT OPEN.
LOW AIR PRESSURE SWITCH—SHUTS FUEL OFF DUE TO LOW AIR PRESSURE.
*STACK SWITCH—SHUTS OFF MOTOR AND OPERAT REACHES TOO HIGH A TEMPERATURE. ALSO SHUTS DOWN THE MOTOR IN THE EVENT OF IGN
*HIGH TEMPERATURE SWITCH—SHUTS OFF MOTOR HIGH A STEAM TEMPERATURE.
* If either device shuts down steam generator, the coils should be refilled with water.
RESISTOR CABINET
CONTROL PANEL
ROTARY CONVERTER
RESET
12- MOTOR OVERLOAD RESET SWITCH
MAIN SWITCH
IGNITION SWITCH
NO. 7625-E REMOTE CONTROL 56- PANEL AND CABINET
BOILER OFF
HOT ENGINE
LOW OIL
TRAIN LINE SHUT-OFF
SOOT BLOWER
MASTER SWITCH
SEPARATOR BLOWDOWN
STEAM TRAIN LINE PRESSURE-44
NO. 7630 ELECTRO-PNEUMATIC CONTROL CABINET
BLOW OUT HOURLY PRESSURE WITH SEV 3-SEC. ALTERNATE B ALSO BLOW OUT W
AIR LINES
STEAM SHUT-OFF CO
MAGNETIC STEA TRAIN LINE SHUT-OFF VALV
9- NOZZLE FUEL PRESSURE GAUGE (MAXIMUM 32 LBS.)
49- STEAM PRESSURE GAUGE (0 TO 250 LBS.)
4- ATOMIZING AIR PRESSURE GAUGE (MAXIMUM 22 LBS.)
21- FUEL MANIFOLD PRESSURE GAUGE (MAXIMUM 70 TO 80 LBS.)
STEAM PRESSURE SWITCH - 45 (SET TO DESIRED MAXIMUM PRESSURE. PREFERABLY NOT LESS THAN 150 LBS.)
20- OPERATING SWITCH
3- ATOMIZING AIR SWITCH
2- AIR REDUCING VALVE
1- ATOMIZING AIR SHUTOFF VALVE
6- FUEL STRAINER
6- AIR STRAINER
FUEL SOLENOID VALVE
FUEL SPRAY HEAD - 7
STACK SWITCH - 5 900° F.
GENERATOR
STEAM ADMISS
10- FUEL KEY METERING VALVE
8- SPARK PLUG ASSEMBLY
TRANSFORMER
CENTRALIZING CONE
STACK
RESET BUTTON
SOOT BLOWER VALVES - 58
HIGH TEMP. SWITCH-23
FUEL OIL TANK 25
SUMP
EMERGENCY FUEL CUTOFF VALVE
26- PUROLATOR OIL FILTER
MANUAL FUEL BY-PASS VALVE
RELIEF VALVE (70-80 LBS.)
24- FUEL CONTROL MANIFOLD
FUEL OIL FILTER - 22
11- BLOWER
FIRE POT
AIR RING
FIRE POT REFRACTORY
15- MOTOR
AIR CYLINDERS
SOOT LANCE
SAFETY VALVES
STEAM
3 TRY COCKS - 50
30- WATER PUMP TEST VALVE
32- AIR BLEEDER VALVES (SUCTION TEST PLUGS)
18- WATER PRESSURE GAUGE (SHOULD BE STEADY AND NOT OVER 400 LBS.)
FUEL OIL PUMP - 27
19- FUEL CONTROL
CHECK VALVE
OUTER COIL
INTERMEDIATE COIL
INNER COIL
REFRACTORY CEMENT
INSULATING CEMENT
WATER PUMP - 29
WATER RELIEF VALVE - 31 (500-600 LBS.)
COIL SHUTOFF VALVE - 16
COIL BLOWDOWN VALVE - 17
51-
STEAM TRAP - 52
6- STRAINER
14- SOLUTION ADMISSION VALVE
COIL BLOWDOWN VALVE SWITCH
STEAM GENERATOR FEED CHECK VALVE
SOLUTION 15- RETURN LINE
STEAM SEPARATOR BLOW
AIR CYLINDER
CHECK VALVE
34- WATER TREATMENT TANK
DRAIN VALVE - 54
33- WATER SUCTION STOP VALVE
STRAINER SCREEN
DRAIN
WATER TANK 28
36- HEAT EXCHANGER
35- WATER RETURN VALVE
SOLUTION RETURN VALVE - 15 (CLOSED WHILE OPERATING)
DRAIN VALVES - 54
DRAIN VALVE 54
DRAIN
NOTE: SOME STEAM GENERATORS ARE EQUIPP REMOTE CONTROL FOR OPERATION FROM ENG THIS INCLUDES THE NOS. 7625-E AND 7630 PAN THE AIR CYLINDERS ON THE SEPARATOR BLO AND SOOT BLOWER VALVES AND A MAGNETIC SHUT-OFF VALVE.
SCHEMATIC DIAGRAM FO CFK-4225-2A AND CFK-4225-3A VAPOR-CLARKSON STEAM GENERA
VAPOR HEATING CORPORATION, RAILWAY EXCHANGE, CHICAGO, ILL.


COLOR CODE
COLD WATER
HOT WATER
STEAM
FUEL OIL
AIR
WASHOUT
RESISTOR CABINET
CONTROL PANEL
ROTARY CONVERTER
IGNITION SWITCH
ELECTRICAL CONTROL DATA
STEAM PRESSURE SWITCH—CONTROLS AND VARIES THE FIVE SPEEDS OF THE MOTOR.
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BOILER OFF
HOT ENGINE
LOW OIL
TRAIN LINE SHUT-OFF
SOOT BLOWER
MASTER SWITCH
SEPARATOR BLOWDOWN
STEAM TRAIN LINE PRESSURE-44
NO. 7630 ELECTRO-PNEUMATIC CONTROL CABINET-57
BLOW OUT HOURLY. USE 150 LB. PRESSURE WITH SEVERAL 3-SEC. ALTERNATE BLOWS. ALSO BLOW OUT WHEN STOPPING.
AIR LINES
STEAM SHUT-OFF COCKS
MAGNETIC STEAM TRAIN LINE SHUT-OFF VALVE-42
9- NOZZLE FUEL PRESSURE GAUGE (MAXIMUM 32 LBS.)
49- STEAM PRESSURE GAUGE (0 TO 250 LBS.)
STEAM PRESSURE SWITCH-45 (SET TO DESIRED MAXIMUM PRESSURE, PREFERABLY NOT LESS THAN 150 LBS.)
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26- PUROLATOR OIL FILTER
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FUEL OIL FILTER-22
11- BLOWER
FIRE POT
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OUTER COIL
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CHECK VALVE
TREATMENT TANK
DRAIN VALVE-54
STRAINER SCREEN
DRAIN
STEAM SEPARATOR BLOWDOWN VALVE-53
15- SOLUTION RETURN LINE
AIR CYLINDER
36- HEAT EXCHANGER
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SOLUTION RETURN VALVE-15 (CLOSED WHILE OPERATING)
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DRAIN
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SCHEMATIC DIAGRAM FOR CFK-4225-2A AND CFK-4225-3A TYPE VAPOR-CLARKSON STEAM GENERATING UNITS

VAPOR HEATING CORPORATION, RAILWAY EXCHANGE, CHICAGO, ILL.

GENERAL DATA

LOCOMOTIVE

	660 HP Switcher	1000 HP Switcher	1000 HP Road Switcher
Diesel Engine B.H.P.	660	1000	1000
No. Traction Motors	4	4	4
Max. Speed Restr. -MPH (With 75/16 Gearing)	60	60	60
No. Driving Wheels-Prs.	4	4	4
Dia. Driving Wheels	40''	40''	40''
Wgt. On Drivers-Tons	99	115	120
Total Loco. Wgt.-Tons	99	115	120
Wheel Base			
Each Truck (rigid)	8' 0''	8' 0''	9' 4''
Total Locomotive	30' 0''	30' 6''	40' 4''
Max. Overall Dimen.-Drg.			
Height	14' 4''	14' 6''	14' 6''
Width	10' 0''	10' 0''	10' 0''
Length (Inside Knuckles)	44' 5 3/4''	45' 5 3/4''	54' 11 3/4''
Starting Tractive Effort (At 30% Adhesion)	59,700	69,000	72,400

	660 HP Switcher	1000 HP Switcher	1000 HP Road Switcher
Min. Radius Curvature (Locomotive Alone)	50'	50'	100'
Brake Equipment (W.A.B. Schedule)	14 EL	14 EL	14 EL
Supplies (Sys. Capacity)			
Lube. Oil-Gals.	80	80	80
Fuel-Gals.	635	635	--
Engine Cooling Water-Gals.	220	240	240
Water Expansion Tank-Gals.	50	50	50
Sand-Cu. Ft.	27	27	27
If Boiler is Applied			
Boiler Water Tank-Gals.	--	--	800
Fuel Oil Tank-Gals.	--	--	800
Boiler Not Applied			
Fuel Oil Tank (2) Gals.	--	--	1600
Air Compressor-Gals. Oil	3	3	3
Journal Size	7" x 14" 6-1/2" x 12"	7" x 14" 6-1/2" x 12"	7" x 14" 6-1/2" x 12"

AUXILIARY DRIVES AND HP REQUIREMENTS

This is the sum of all auxiliaries operating from the engine. These vary, but typical values are as follows:

	HP
Compressor at 740 RPM against full pressure	54
Traction motor blowers (2) at full speed	11
Radiator Fan - 660 HP Engine	14
- 1000 HP Engine	20
Aux. Generator for control, battery charge, lights, etc.	Idling-7 Max. RPM-7

ROTATING APPARATUS MAX. SPEED

	RPM
Diesel Engine	740
Traction Motor Blower	2160
Radiator Fan - 660 HP Engine	900
- 1000 HP Engine	1000
Aux. Generator and Exciter	1776
Air Compressor	740
Motor Driven Fuel Pump	1725
Cab Heater Motor	2500
Traction Generator	740
Lubricating Oil Pump	1675
Water Pump	1775

DIESEL ENGINE

	660 HP Switcher	1000 HP Switcher and Road Switcher
Engine HP	660	1000
Rated Engine Speed	740 RPM	740 RPM
Idling Speed	275 RPM	275 RPM
Bore and Stroke	12½ x 13	12½ x 13
No. of Cylinders	6	6
Cu. In. Displacement	9,572	9,572
Turbocharger	No	Yes
Nozzle Opening Pressure		
New & Reconditioned	3800 PSI	3800 PSI
Desired Operating	3600 PSI	3600 PSI
Fuel Pump Timing	15° BTC	15° BTC
Max. Fuel Pump Rack Setting	24 MM	22.5 MM
Valve Timing		
Air Valve Opens	15° BTC	80° BTC
Air Valve Closes	45° ABC	35° ABC
Exhaust Valve Opens	50° BBC	50° BBC
Exhaust Valve Closes	20° ATC	54° ATC
Firing Order	1-3-5-6-4-2	1-3-5-6-4-2

TABLE OF CLEARANCES

ITEM	NEW	LIMITS
Valve Tappet		
Air inlet valve	.016 hot or cold	
Exhaust valve	.016 hot or cold	
Valve Guides		
Air inlet valve	.003 - .006	.015
Exhaust valve	.007 - .010	.015
Valve Lever Bushings		
Air inlet valve lever	.003 - .005	.010
Exhaust valve lever	.004 - .006	.010
Push Rod Lifter Bushings		
Shaft	.0015-.0035	.006
Roller pin	.002 - .004	.007
Main Bearings		
Running clearance	.006 - .010	.014
Crankshaft Thrust		
Total	.009 - .015	.025
Connecting Rod Bearings		
Running clearance	.006 - .009	.011
Piston Pins		
In bushings	.003 - .0045	.008
In bosses	.0005- .002	.004

ITEM	NEW	LIMITS
Camshaft Bearings		
All bushings	.0045- .007	.014
End bearing	.006 - .008	.015
Total thrust	.006 - .015	.025
Fuel Pump Shaft Bearings		
F. P. Camshaft bushings	.003 -.0055	.009
End bearing	.006 - .008	.015
Thrust bushing	.0035- .007	.014
Total thrust	.006 - .015	.025
Pistons		
Dia. at skirt bottom	12.481-12.482	12.476
Head clearance (vertical)	3/16	--
Piston Rings (Measured in a 12.500" dia. liner)		
Compression (gap)	.035 - .050	100% inc.
Compression (side)	.0075-.0105	100% inc.
Oil scraper (gap)	.035 - .050	50% inc.
Oil scraper (side)	.005 -.0075	50% inc.
Gear Backlash Between Each Pair Of Gears		
Gear train	.008 - .011	50% inc.
Governor bevel gears	.012 - .015	--
Governor drive gears	.0025-.0055	--
Lube oil pump drive gears	.003 - .006	50% inc.
Water pump drive gear	.008 - .011	50% inc.
Cylinder Liner		
Diameter	12.501-12.4985	12.580
Top & bottom fit	.000 - .001	--

Water Pump

Capacity	300 GPM @ 740 Engine RPM
Pressure	Idle - 8 PSI Full load -25 PSI

Lubricating Oil Pump

Delivery	64 GPM @ 740 Engine RPM
Pressure	Idle - 26 PSI Full load - 75 PSI (By-pass valve set at 75 PSI)

Fuel Booster Pump

Delivery	3½ GPM @ 1725 RPM

WEIGHTS FOR LIFTING

Item	Pounds		
	660 HP Switcher	1000 HP Switcher	1000 HP Road Switcher
Air Compressor	1400	1400	1400
Axle Gear	500	500	500
Battery - 32 Cells	2136	2136	2136
Battery Tray - 4 Cells	267	267	267
Booster Pump	66	66	66
Camshaft - Fuel (without gear)	56	56	56
Camshaft - Valve (without gear)	250	250	250

Item	Pounds		
	660 HP Switcher	1000 HP Switcher	1000 HP Road Switcher
Camshaft Gear	185	185	185
Crankshaft	3,950	3,950	3,950
Crankshaft Gear	102	102	102
Cylinder Head Assembly	429	429	429
Cylinder Liner	260	260	260
Engine	33,700	34,800	34,800
Engine Base	9,365	9,365	9,365
Engine Frame	6,519	6,519	6,519
Engine, Generator and Muffler	41,050	--	--
Engine, Generator and Turbocharger	--	45,800	45,800
Exciter - Aux. Generator Set	800	800	800
Fuel Nozzle	12	12	12
Fuel Pump	32	32	32
Fuel Pump Assembly (complete)	1,000	1,000	1,000
Generator, Traction	7,000	9,200	9,200
Governor	80	80	80
Idler Gear	54	54	54
Loco. - less Trucks - Tons (Light)	59.1	76.1	73

Item	Pounds		
	660 HP Switcher	1000 HP Switcher	1000 HP Road Switcher
Locomotive - light - Tons	93	110	112.4
Locomotive - with Supplies - Tons	98	115	121
Lube Oil Pump Assembly	100	100	100
Muffler	350	--	--
Piston	104	104	104
Piston Pin	32	32	32
Piston, Rod with Cap and Bearings	221	221	221
Radiator Fan Gear Box Unit	145	145	145
Rocker Box Assembly	200	200	200
Traction Motor	5,600	5,600	5,600
Traction Motor Blower	360	360	360
Traction Motor Pinion	50	50	50
Truck - without Motors - Tons	12	12	12
Turbocharger	--	1,800	1,800
Water Pump	114	114	114
Water Pump Gear	19	19	19
Wheel (Motor Truck)	1000	1000	1000
Wheel and Axle Assembly (with Gear)	3,800	3,800	3,800

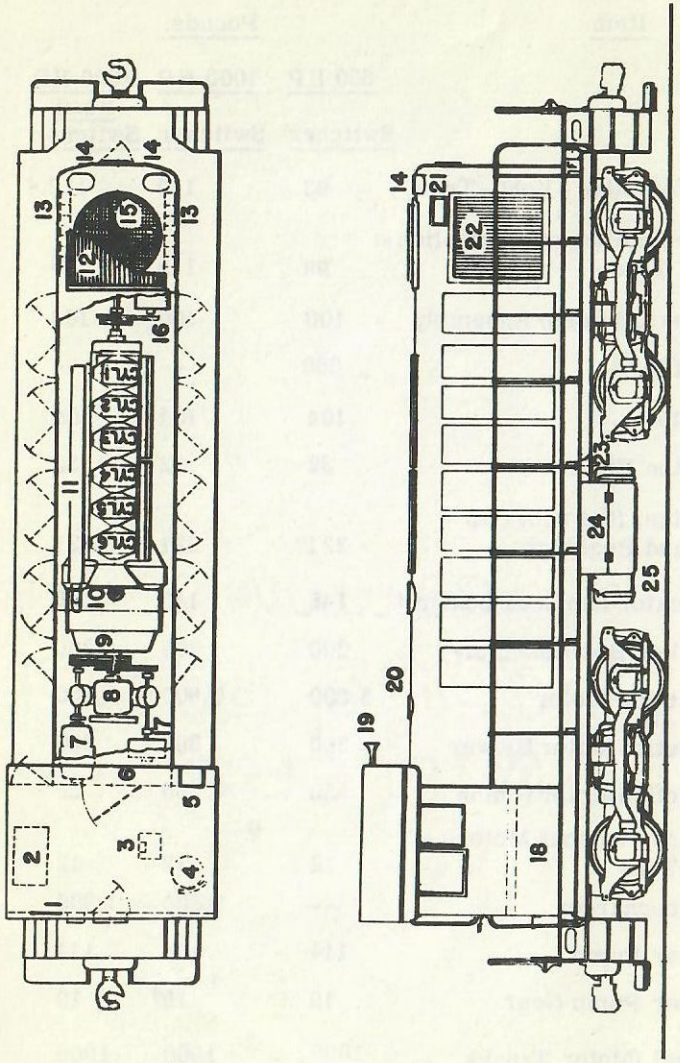


FIG. 1 - 2, PART I
LOCATION OF APPARATUS
660 HP SWITCHER

1. Handbrake
2. Fireman's Seat Box
3. Control Stand
4. Engineer's Seat
5. Cab Heater
6. Contactor Compartment
7. Auxiliary Generator and Exciter
8. Air Compressor
9. Main Generator
10. Muffler
11. Engine
12. Fan Opening Shutter
13. Radiators
14. Front Sand Boxes
15. Radiator Fan
16. Front Traction Motor Blower
17. Rear Traction Motor Blower
18. Fuel Tank
19. Horn
20. Rear Sand Box
21. Number Lights
22. Radiator Shutters
23. Bell
24. Battery
25. Main Reservoir

FIG. 1 - 2, PART II
LOCATION OF APPARATUS
660 HP SWITCHER

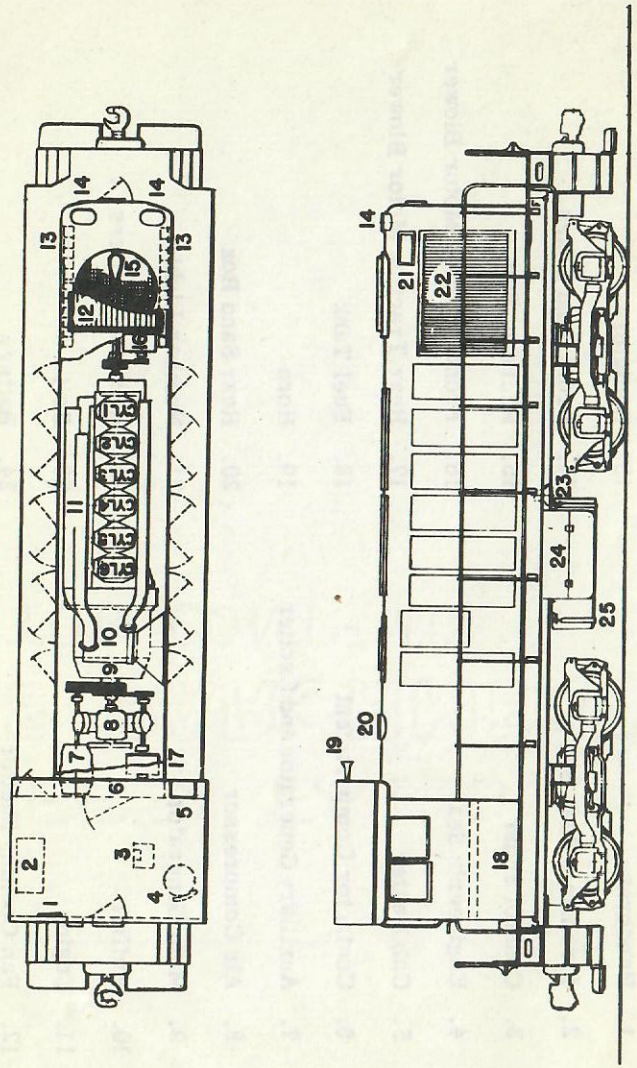


FIG. 2 - 2, PART I
LOCATION OF APPARATUS
1000 HP SWITCHER

1. Handbrake
2. Fireman's Seat Box
3. Control Stand
4. Engineer's Seat
5. Cab Heater
6. Contactor Compartment
7. Auxiliary Generator and Exciter
8. Air Compressor
9. Main Generator
10. Turbocharger
11. Engine
12. Fan Opening Shutter
13. Radiators
14. Front Sand Boxes
15. Radiator Fan
16. Front Traction Motor Blower
17. Rear Traction Motor Blower
18. Fuel Tank
19. Horn
20. Rear Sand Box
21. Number Lights
22. Radiator Shutters
23. Bell
24. Battery
25. Main Reservoir

FIG. 2 - 2, PART II
LOCATION OF APPARATUS
1000 HP SWITCHER

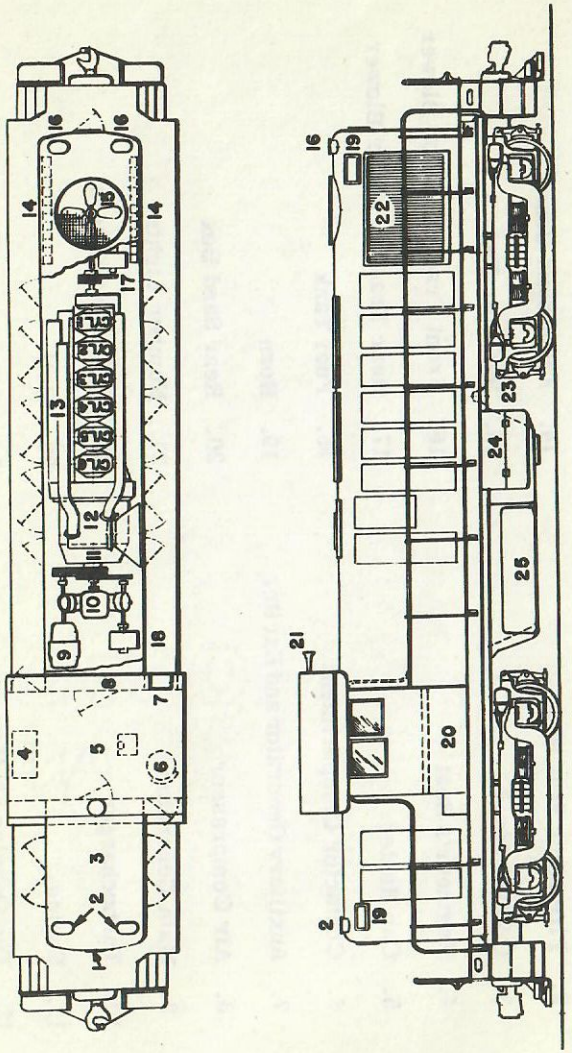


FIG. 3 - 2; PART I
LOCATION OF APPARATUS
1000 HP ROAD SWITCHER

1. Handbrake
2. Rear Sand Boxes
3. Steam Generator Compartment
4. Fireman's Seat Box
5. Control Stand
6. Engineer's Seat
7. Cab Heater
8. Contactor Compartment
9. Auxiliary Generator and Exciter
10. Air Compressor
11. Main Generator
12. Turbocharger
13. Engine
14. Radiators
15. Radiator Fan
16. Front Sand Boxes
17. Front Traction Motor Blower
18. Rear Traction Motor Blower
19. Number Lights
20. Steam Generator Water Tank or Fuel Tank
21. Horn
22. Radiator Shutters
23. Bell
24. Battery
25. Fuel Tank

FIG. 3 - 2, PART II
LOCATION OF APPARATUS
1000 HP ROAD SWITCHER

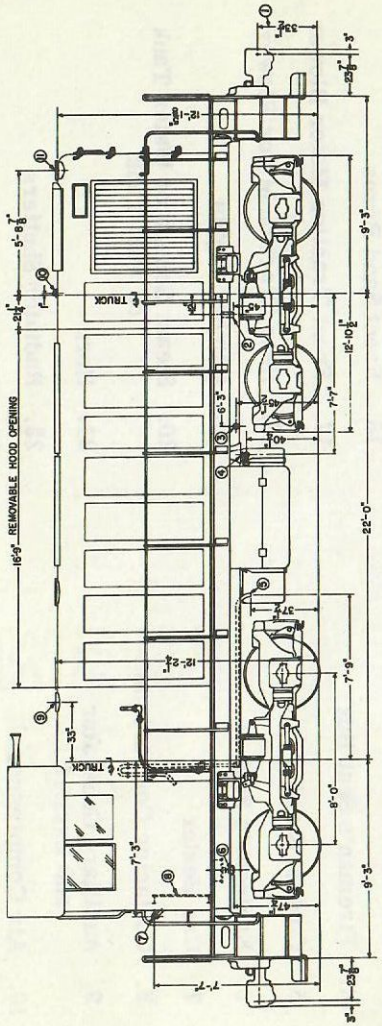


FIG. 4 - 2, PART I
FILLERS AND DRAINS
660 HP SWITCHER

1. Coupler Height - Drawing Dimension.
2. Water Expansion Tank Overflow - L.S. - 3/4'' Pipe.
3. Engine Water Filler and Drain - L.S. - NYABCO Hose Coupling.
4. Engine Lube Oil Drain - L.S. - $1\frac{1}{2}$'' Pipe with Cap and Valve.
5. Fuel Tank Overflow - R.S. - 2'' Pipe.
6. Fuel Tank Drain - L.S. - $1\frac{1}{2}$'' Globe Valve.
7. Fuel Tank Filler - R.S. - 3'' Pipe with Cap.
8. Fuel Tank Gauge Glass - 5/8'' O.D. 19 5/8'' Long.
9. Rear Sand Box on Locomotive Centerline - 9 3/4'' Diameter. Filling Hole - $13\frac{1}{2}$ CU. FT. Capacity.
10. Engine Water Roof Filler on Locomotive Centerline - 2'' Pipe with Cap.
11. Front Sand Boxes - One Each Side - 9 5/8'' x 16 5/8'' Openings 6 3/4'' CU. FT. Capacity Each Side.

FIG. 4 - 2, PART II
FILLERS AND DRAINS
660 HP SWITCHER

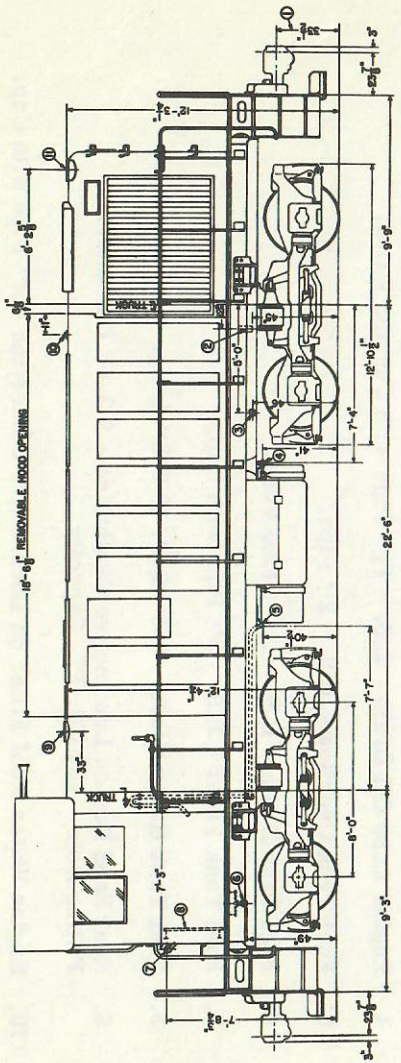


FIG. 5 - 2, PART I
FILLERS AND DRAINS
1000 HP SWITCHERS

1. Coupler Height - Drawing Dimension.
2. Water Expansion Tank Overflow - L.S. - 3/4'' Pipe.
3. Engine Water Filler and Drain - L.S. - NYABCO Hose Couplings.
4. Engine Lube Oil Drain - L.S. - $1\frac{1}{2}$'' Pipe with Cap and Valve.
5. Fuel Tank Overflow - R.S. - 2'' Pipe.
6. Fuel Tank Drain - L.S. - $1\frac{1}{2}$'' Globe Valve.
7. Fuel Tank Filler - R.S. - 3'' Pipe with Cap.
8. Fuel Level Gauge Glass - 5/8'' O.D. 19 5/8'' Long.
9. Rear Sand Box on Locomotive Centerline - 9 3/4'' Diameter. Filling Hole - $13\frac{1}{2}$ CU. FT. Capacity.
10. Engine Water Roof Filler on Locomotive Centerline - 2'' Pipe with Cap.
11. Front Sand Boxes - One Each Side - 9 5/8'' x 16 5/8'' Openings - 6 3/4'' CU. FT. Capacity Each Side.

FIG. 5 - 2, PART II
FILLERS AND DRAINS
1000 HP SWITCHER

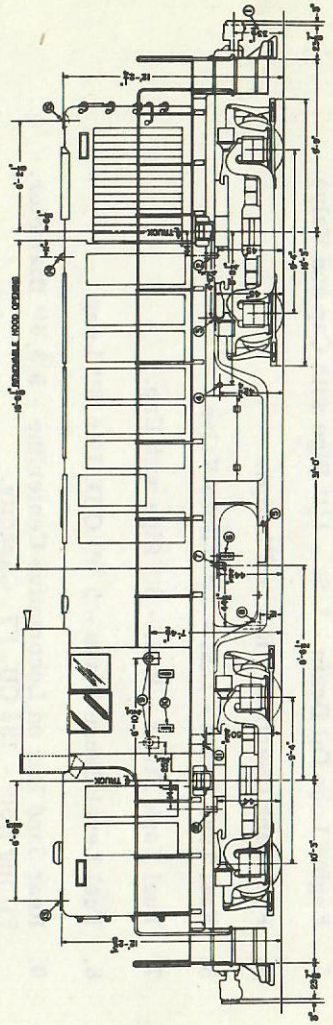


FIG. 6 - 2, PART I
FILLERS AND DRAINS
1000 HP ROAD SWITCHER

1. Coupler Height - Drawing Dimension.
2. Water Expansion Tank Overflow - L.S. - 3/4'' Pipe.
3. Engine Water Filler and Drain - L.S. - NYABCO Hose Coupling.
4. Engine Lube Oil Drain - L.S. - $1\frac{1}{2}$'' Pipe with Cap and Valve.
5. Lower Fuel Tank Drain - $1\frac{1}{2}$'' Valve.
6. Lower Fuel Tank Gauge.
7. Lower Fuel Tank Filler - R.S. and L.S. - 4'' Pipe with plug when upper tank is used for fuel. When upper tank is used for steam generator water, remove Protecto-Seals #384 from upper tank filling pipes and apply them to lower tank. Apply plugs in upper tank.
8. Lower Fuel Tank Overflow - L.S. - 2'' Pipe.
9. Upper Fuel Tank Filler - R.S. and L.S. - 4'' Pipe with #384 Protecto-Seals. This tank is used for water when steam generator is applied.
10. Upper Tank Gauges.
11. Upper Tank Drain - L.S. - $1\frac{1}{2}$'' Pipe with Plug.
12. Upper Tank Overflow - L.S. - 2'' Pipe
13. Rear Sand Box on Locomotive Centerline - 9 3/8'' Square Filling Hole - $14\frac{1}{2}$'' CU. FT. Capacity.
14. Engine Water Roof Filler on Locomotive Centerline - 2'' Pipe with Cap.
15. Front Sand Boxes - One Each Side - 9 5/8'' x 16 5/8'' Openings - 6 3/4'' CU. FT. Capacity Each Side.

FIG. 6 - 2, PART II
FILLERS AND DRAINS
1000 HP ROAD SWITCHER

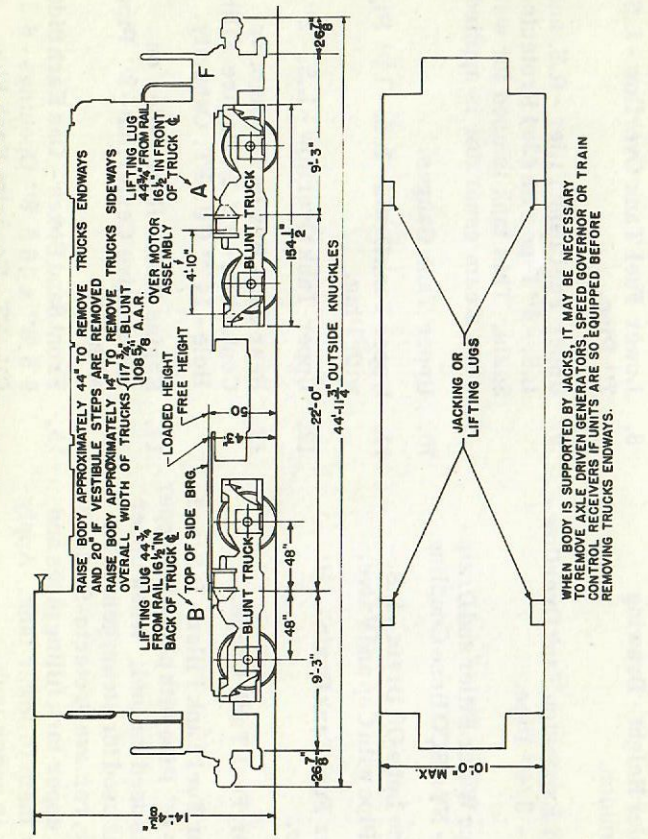

WARNING: WHEN RAISING LOCOMOTIVE FOR TRUCK REMOVAL THE END OPPOSITE FROM THE TRUCK TO BE REMOVED MUST BE RAISED HIGH ENOUGH TO SEPARATE THE CENTER PLATES TO PREVENT SEIZING OR BREAKING OF THE TRUCK CENTER CASTING.
RAISE BODY APPROXIMATELY 44" TO REMOVE TRUCKS ENDWAYS AND 20" IF VESTIBULE STEPS ARE REMOVED
RAISE BODY APPROXIMATELY 14" TO REMOVE TRUCKS SIDEWAYS
OVERALL WIDTH OF TRUCKS 117 3/4", BLUNT 108 5/8" A.A.R.
LIFTING LUG 44 3/4" FROM RAIL 16 1/2" IN FRONT OF TRUCK ℄
LOADED HEIGHT
FREE HEIGHT
TOP OF SIDE BRG.
BLUNT TRUCK
48"
48"
9'-3"
22'-0"
44'-1 3/4" OUTSIDE KNUCKLES
JACKING OR LIFTING LUGS
10'-0" MAX.
WHEN BODY IS SUPPORTED BY JACKS, IT MAY BE NECESSARY TO REMOVE AXLE DRIVEN GENERATORS, SPEED GOVERNOR OR TRAIN CONTROL RECEIVERS IF UNITS ARE SO EQUIPPED BEFORE REMOVING TRUCKS ENDWAYS.

FIG. 7 - 2, PART I
JACKING AND LIFTING
660 HP SWITCHER

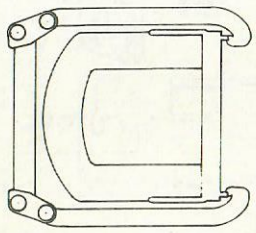
① JACKING AND LIFTING DATA WITH TRUCKS ATTACHED
SEE TABLE BELOW-LINES 1 THRU 3

② JACKING AND LIFTING DATA WITHOUT TRUCKS
SEE TABLE BELOW - LINE 4

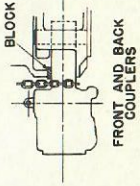
LOADED WEIGHT STD. LOCO.

LINE	JACK OR LIFT AT	FULCRUM	LOAD "A"	LOAD "B"	RAIL LOAD FT. TRUCK	RAIL LOAD BK. TRUCK
1	A	BK. TRUCK	93,900	—	—	104,000
2	B	FT. TRUCK	—	92,840	105,060	—
3	A & B	—	99,480	98,420	—	—
4	A & B	—	64,480	63,420	—	—

LOADED WEIGHTS
WEIGHT OF ONE MOTOR TRUCK COMPLETE 35,000 LBS. BLUNT 34,000 LBS. A.A.R.



CONSTRUCTION DRG. 994S977240 OF THE LIFTING RIG MAY BE OBTAINED FROM THE AMERICAN LOCOMOTIVE COMPANY.



NOTE: LIFTING BY COUPLER SHOULD ONLY BE DONE IN AN EMERGENCY AS IT MAY RESULT IN DAMAGE TO THE COUPLER OR YOKE AND BENDING OF THE DRAFT GEAR SUPPORT.

FIG. 7 - 2, PART II
JACKING AND LIFTING
660 HP SWITCHER

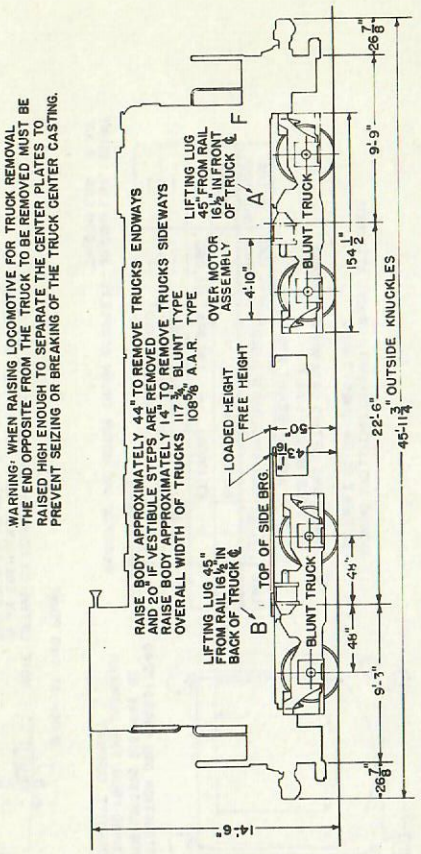
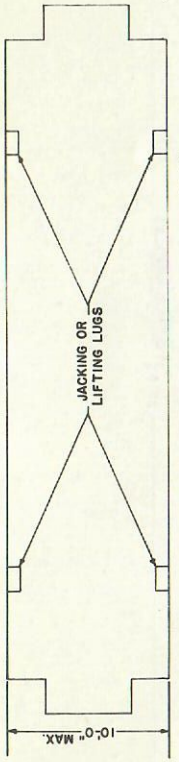

WARNING: WHEN RAISING LOCOMOTIVE FOR TRUCK REMOVAL THE END OPPOSITE FROM THE TRUCK TO BE REMOVED MUST BE RAISED HIGH ENOUGH TO SEPARATE THE CENTER PLATES TO PREVENT SEIZING OR BREAKING OF THE TRUCK CENTER CASTING.
RAISE BODY APPROXIMATELY 44" TO REMOVE TRUCKS ENDWAYS AND 20" IF VESTIBULE STEPS ARE REMOVED
RAISE BODY APPROXIMATELY 147" TO REMOVE TRUCKS SIDEWAYS
OVERALL WIDTH OF TRUCKS 117 3/4" BLUNT TYPE 108 7/8" A.A.R. TYPE
LIFTING LUG 45" FROM RAIL 16 1/2" IN FRONT OF TRUCK ℄
OVER MOTOR ASSEMBLY
LOADED HEIGHT
FREE HEIGHT
TOP OF SIDE BRG
BLUNT TRUCK
154 1/2"
9'-9"
26 7/8"
4'-10"
50"
43"
22'-6"
45-11 3/4" OUTSIDE KNUCKLES
48"
4'-1"
9'-3"
26 7/8"
14'-6"
A
B
F

FIG. 8 - 2, PART I
JACKING AND LIFTING
1000 HP SWITCHER



WHEN BODY IS SUPPORTED BY JACKS, IT MAY BE NECESSARY TO REMOVE AXLE DRIVEN GENERATORS SPEED GOVERNOR OR TRAIN CONTROL RECEIVERS IF UNITS ARE SO EQUIPPED BEFORE REMOVING TRUCKS ENDWAYS.

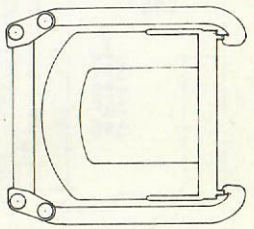
① JACKING AND LIFTING DATA WITH TRUCKS ATTACHED
SEE TABLE BELOW-LINES 1 THRU 3

② JACKING AND LIFTING DATA WITHOUT TRUCKS
SEE TABLE BELOW - LINE 4

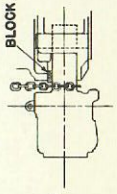
LOADED WTS. STANDARD LOCO.

LINE	JACK OR LIFT AT	FULCRUM	LOAD "A"	LOAD "B"	RAIL LOAD FT. TRUCK	RAIL LOAD BK. TRUCK
1	A	BK. TRUCK	108,000	—	—	122,000
2	B	FT. TRUCK	—	109,000	121,000	—
3	A & B	—	114,500	115,500	—	—
4	A & B	—	79,500	80,500	—	—

LOADED WEIGHTS
WEIGHT OF ONE MOTOR TRUCK COMPLETE 35,000 LBS. BLUNT
34,000 LBS. A.A.R.



CONSTRUCTION DRG. 9945977240 OF THE LIFTING RIG MAY BE OBTAINED FROM THE AMERICAN LOCOMOTIVE COMPANY.



NOTE: LIFTING BY COUPLER SHOULD ONLY BE DONE IN AN EMERGENCY AS IT MAY RESULT IN DAMAGE TO THE COUPLER OR YOKE AND BENDING OF THE DRAFT GEAR SUPPORT.

FIG. 8 - 2, PART II
JACKING AND LIFTING
1000 HP SWITCHER

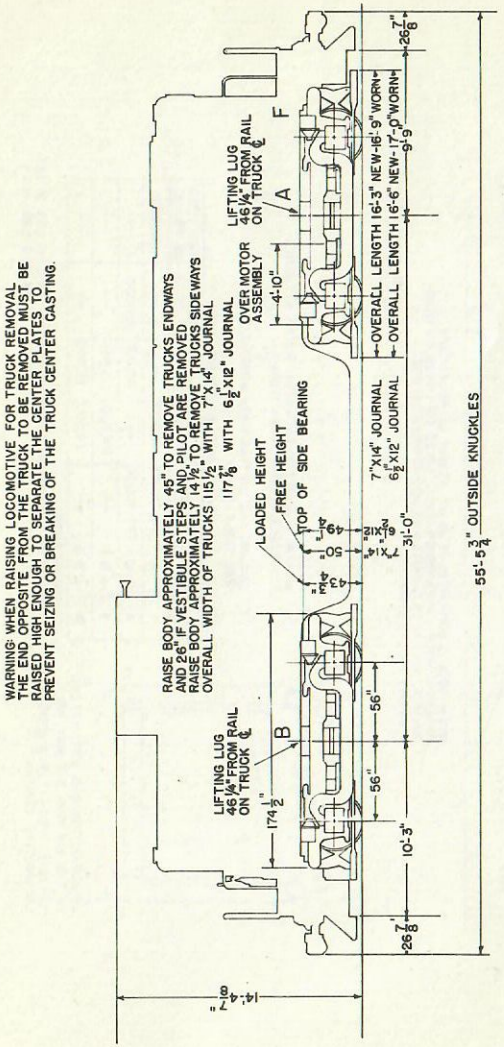
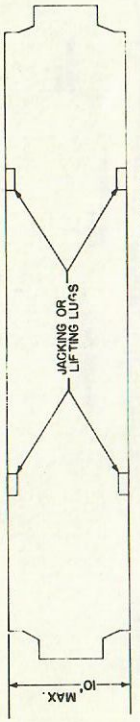

WARNING: WHEN RAISING LOCOMOTIVE FOR TRUCK REMOVAL THE END OPPOSITE FROM THE TRUCK TO BE REMOVED MUST BE RAISED HIGH ENOUGH TO SEPARATE THE CENTER PLATES TO PREVENT SEIZING OR BREAKING OF THE TRUCK CENTER CASTING.
RAISE BODY APPROXIMATELY 45" TO REMOVE TRUCKS ENDWAYS AND 26" IF VESTIBULE STEPS AND PILOT ARE REMOVED
RAISE BODY APPROXIMATELY 141/2" TO REMOVE TRUCKS SIDEWAYS
OVERALL WIDTH OF TRUCKS 115 1/2" WITH 7"X14" JOURNAL 117 7/8" WITH 6 1/2"X12" JOURNAL
LIFTING LUG 46 1/4" FROM RAIL ON TRUCK ℄
LIFTING LUG 46 1/4" FROM RAIL ON TRUCK ℄
OVER MOTOR ASSEMBLY
LOADED HEIGHT
FREE HEIGHT
TOP OF SIDE BEARING
OVERALL LENGTH 16'-3" NEW-16'-9" WORN
OVERALL LENGTH 16'-6" NEW-17'-0" WORN
7"X14" JOURNAL
6 1/2"X12" JOURNAL
55'-5 3/4" OUTSIDE KNUCKLES
A
B
F

FIG. 9 - 2, PART I
JACKING AND LIFTING
1000 HP ROAD SWITCHER



WHEN BODY IS SUPPORTED BY JACKS, IT MAY BE NECESSARY TO REMOVE AXLE DRIVEN GENERATORS, SPEED GOVERNOR OR TRAIN CONTROL RECEIVERS IF UNITS ARE SO EQUIPPED BEFORE REMOVING TRUCKS SIDEWAYS.

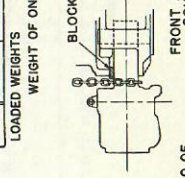
① JACKING AND LIFTING DATA WITH TRUCKS ATTACHED
SEE TABLE BELOW-LINES 1 THRU 3

② JACKING AND LIFTING DATA WITHOUT TRUCKS
SEE TABLE BELOW-LINE 4

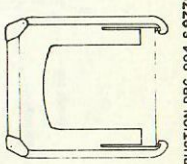
MAXIMUM LOADED WEIGHT

LINE	JACK OR LIFT AT	FULCRUM	LOAD "A"	LOAD "B"	RAIL LOAD FT. TRUCK	RAIL LOAD BK. TRUCK
1	A	EK. TRUCK	122700	—	—	128,500
2	B	FT. TRUCK	—	128,500	122,700	—
3	A & B	—	122,700	128,500	—	—
4	A & B	—	83,200	89,000	—	—

LOADED WEIGHTS
WEIGHT OF ONE MOTOR TRUCK COMPLETE { 40,000 LBS. (7"X14" JOURNAL TRUCK) 39,500 LBS. (6 1/2"X12" JOURNAL TRUCK)



NOTE: LIFTING BY COUPLER SHOULD ONLY BE DONE IN AN EMERGENCY AS IT MAY RESULT IN DAMAGE TO THE COUPLER OR YOKE AND BENDING OF THE DRAFT GEAR SUPPORT.



CONSTRUCTION DRG 994 S 977240 OF THE LIFTING RIG MAY BE OBTAINED FROM THE AMERICAN LOCOMOTIVE COMPANY.

FIG. 9 - 2, PART II
JACKING AND LIFTING
1000 HP ROAD SWITCHER

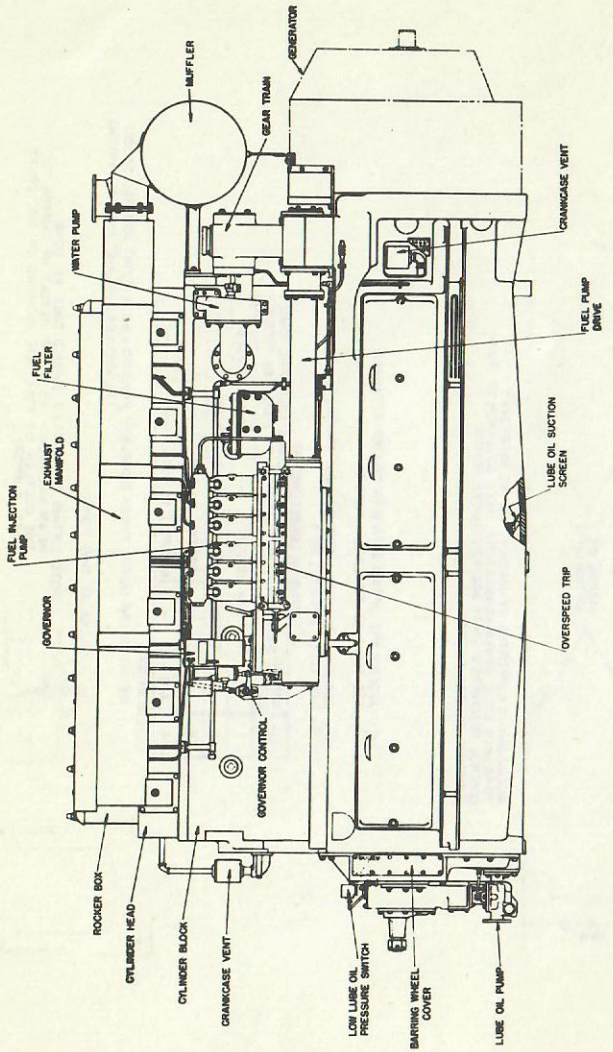


FIG. 10 - 2
ELEVATION - 660 HP ENGINE

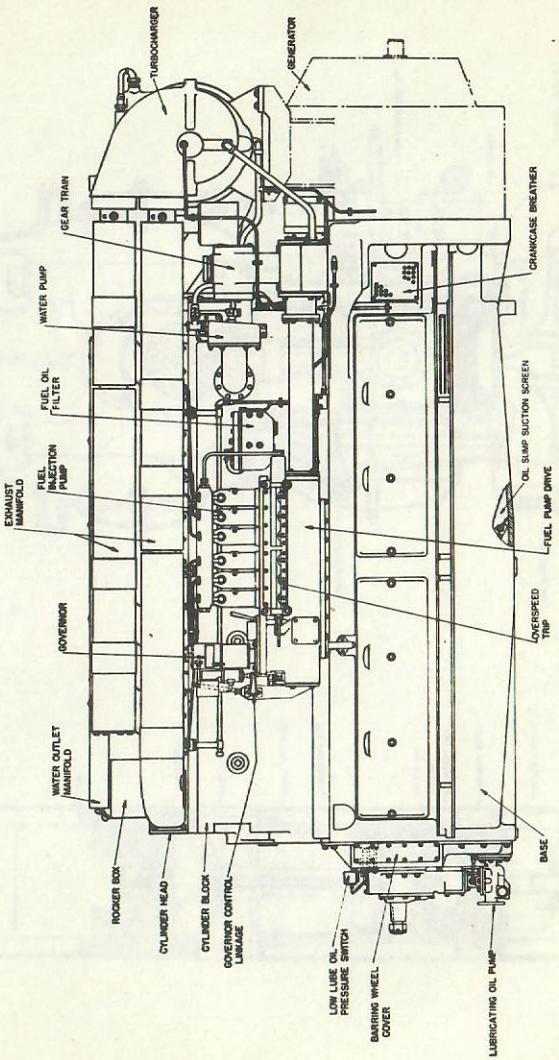


FIG. 11 - 2
ELEVATION - 1000 HP ENGINE

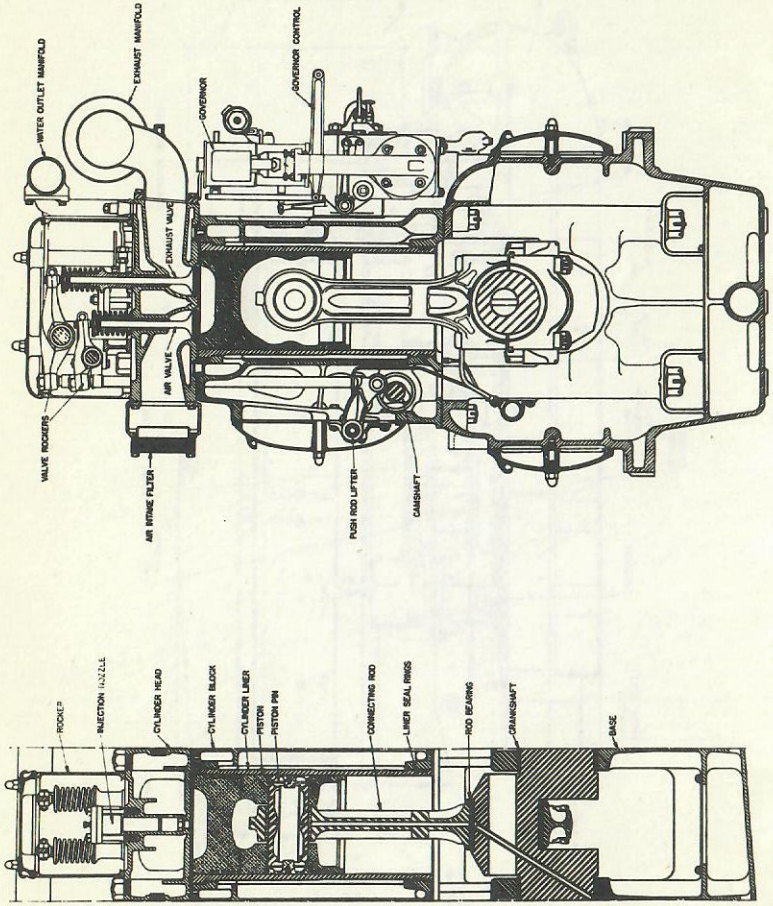
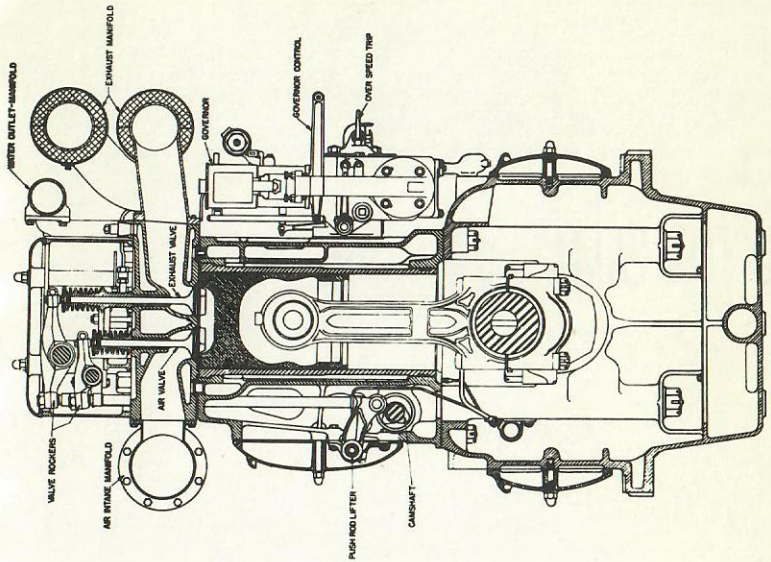


FIG. 12 - 2
CROSS SECTION - 660 HP ENGINE



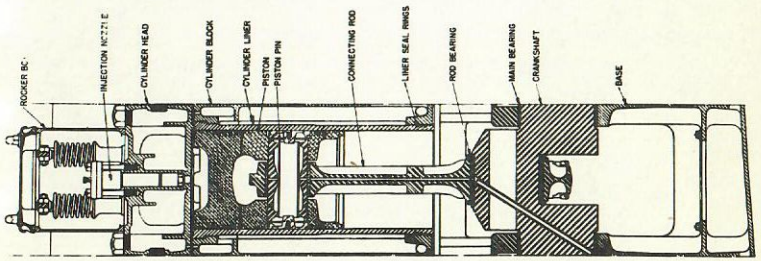


FIG. 13 - 2
CROSS SECTION - 1000 HP ENGINE

NOTES

DIESEL ENGINE

WOODWARD GOVERNOR

DESCRIPTION

This is a type "SI" governor equipped with special speed adjusting mechanism and special power cylinder.

The function of these special parts is: (1) to permit adjustment of the engine speed over its full operating range from the relatively small movement of the engineer's control handle: (2) to provide (A) means of quickly shutting the engine down from the engineer's cab and (B) automatic means of shutting the engine down in the event of low lubricating oil pressure.

To change the operating speed of the engine it is necessary only to change the amount of compression of the speeder spring or speed adjusting spring. The speed adjusting shaft supports and is integral with the speed adjusting lever. The teeth in the segment of the speed lever mesh with corresponding rack teeth in the speeder spring plug. The speeder spring plug bears on the top of the speeder spring. Therefore, a movement of shaft results in a change in the amount of compression of the speeder spring and a corresponding change in engine speed.

The solenoid valve attached to the governor power piston head is used to shut down the Diesel engine. If the engine lubricating oil pressure should fall below 23 pounds or if the fuel pump button in the cab is pulled, the solenoid will be de-energized. This opens the solenoid valve and relieves the oil pressure under the power pistons. Then the power spring will force the piston down and the fuel racks will move to shut down the position.

The Woodward Governor consists essentially of three elements:

1. The speed measuring device or governor head.
2. The power element which on indication from the governor head, performs the work of changing the amount of fuel injected into the engine cylinders.
3. The stability or compensating element which prevents racing or hunting of the prime mover by stopping the governor movement when this movement is sufficient to bring the speed back to normal.

In the following schematic drawings, the movements of the governor parts have been exaggerated to make them more visible. The part called the receiving compensating plunger is really the lower end of the pilot valve bushing and therefore moves with it. The actuating compensating plunger (also called the compensating piston) and the power piston are also rigidly connected and move together.

Assume that the engine is running at normal speed as shown on the speed indicator, Fig. 1-3 and carrying half load as shown on the indicator. Assuming also that all governor adjustments are properly set, the flyballs, pilot valve plunger and pilot valve bushing are centered and the port in the pilot valv e bushing is exactly covered by the lower disc of the pilot valve plunger. The power piston is stationary at a position corresponding to about half load on the engine.

If a certain percentage of load is dropped from the engine the speed starts to rise and the flyballs move outward a distance proportionate to the speed change, Fig. 2-3. This movement forces the pilot valve plunger upward a proportionate distance against the speed adjustment spring (also called speeder spring).

The port in the pilot valve bushing is uncovered, opening the port Y-1 to the discharge sump area D-1.

This permits the power spring to push the power piston downward. The piston rod, being mechanically connected to the fuel control mechanism, move the mechanism in the direction to reduce the supply of fuel being delivered to the engine and therefore, to reduce the engine speed.

As the power piston moves downward a vacuum is formed in area X-1, also, through the compensating needle valve to relieve the vacuum and allow the compensating spring to recenter the receiving plunger. The passage through the needle valve is very small, however, the amount of oil coming through does not have any great effect on the vacuum while the power piston is in motion but has considerable effect the instant the power piston stops moving. Note that whereas in Fig. 2-3 the port in the pilot valve bushing was fully uncovered, it is now about half covered due to the upward movement, Fig. 3-3.

As the power piston continues to move downward the pilot valve bushing moves upward until the port in the pilot valve bushing is again exactly covered by the lower disc of the pilot valve plunger. See Fig. 4-3. The instant the port is covered the flow of oil from the area Y-1 and the downward movement of the power piston will be stopped. If the ratio of movement of the operating parts of the governor is correct, the amount of fuel supplied to the engine will have been reduced just the amount necessary to accommodate the reduced load and the speed will return to normal.

All that is necessary now is to keep the power piston stationary until the speed returns to normal or a subsequent speed change occurs.

As the engine speed returns to normal the governor flyballs will also return to their central position. As the flyballs return to center the pilot valve plunger will also return to its central position. If the power piston is to be kept stationary the port in the pilot valve bushing must be kept covered.

Consequently, the pilot valve bushing must return to its central position in unison with the flyballs and the pilot valve plunger. This is accomplished by adjusting

the flow of oil through the compensating needle valve to permit the compensating spring to recenter the compensating receiving plunger and pilot valve bushing in exact unison with the return of the speed to normal. After this valve is once adjusted to the response of the particular engine, it need not be changed again. See Fig. 5-3.

Fig. 6-3 shows the completion of the cycle. The pilot valve plunger and pilot valve bushing moved downward to their central position together. The port in the pilot valve bushing remained covered and consequently the power piston remained stationary. All of the operating parts are in their original positions with the exception of the power piston, which is in the position corresponding to the reduced load in the engine.

The cycle of operation for an increase in load is just the reverse of that described above. Load is thrown on the engine — the speed decreases — the flyballs move inward — the speed adjusting spring pushes the pilot plunger downward uncovering the pilot valve bushing port — pressure oil passing into area Y-1 forces the power piston upward against the downward force of the power spring — the upward movement of the power piston increases the fuel flow and creates pressure in area X-1 which forces the pilot valve bushing downward until the port in the bushing is covered by the lower pilot plunger disc — the power piston stops at the exact position corresponding to the increased load — the speed begins to return to normal — the flyballs move toward their central position — the compensating spring recenters the receiving plunger and bushing in exact unison with the return of the speed to normal by forcing the oil out of area X-1 through the compensating needle valve so that the port in the pilot valve bushing is kept covered. The power piston now remains stationary and the completion of the cycle finds the flyballs, the pilot valve plunger and the pilot valve bushing centered and the power piston in a position corresponding to the increased load.

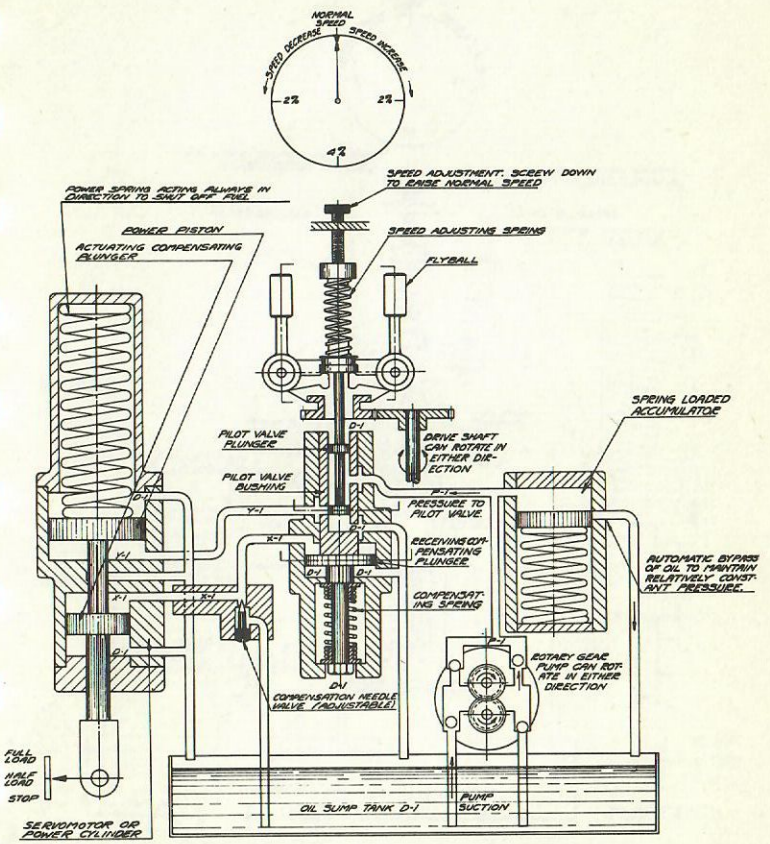


FIG. 1-3

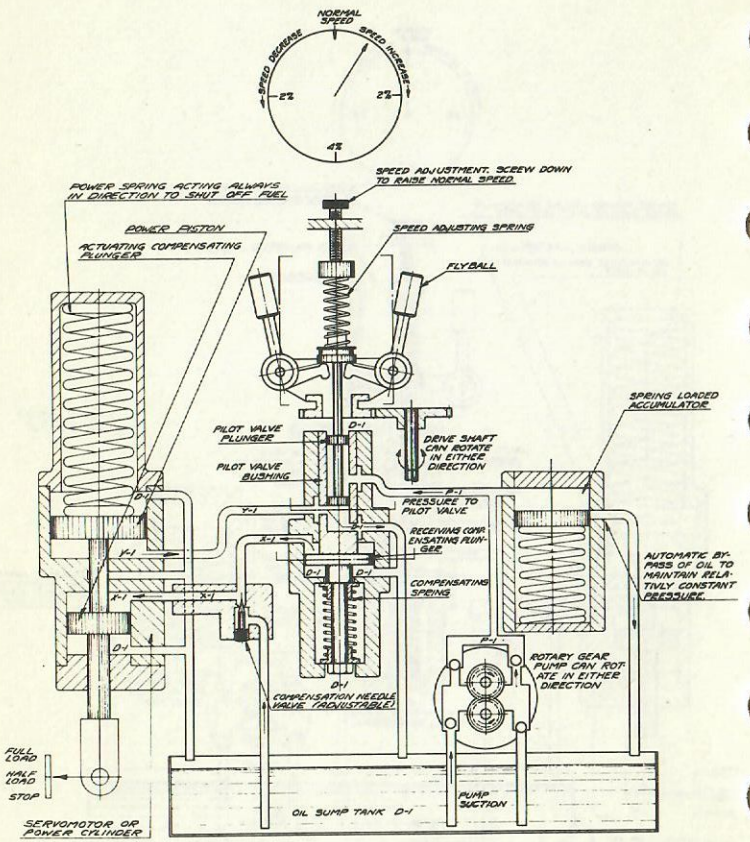

NORMAL SPEED
SPEED DECREASE
SPEED INCREASE
2%
2%
4%
POWER SPRING ACTING ALWAYS IN DIRECTION TO SHUT OFF FUEL
SPEED ADJUSTMENT. SCREW DOWN TO RAISE NORMAL SPEED
POWER PISTON
ACTUATING COMPENSATING PLUNGER
SPEED ADJUSTING SPRING
FLYBALL
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
D-1
DRIVE SHAFT CAN ROTATE IN EITHER DIRECTION
SPRING LOADED ACCUMULATOR
P-1
PRESSURE TO PILOT VALVE
Y-1
X-1
RECEIVING COMPENSATING PLUNGER
COMPENSATING SPRING
AUTOMATIC BYPASS OF OIL TO MAINTAIN RELATIVLY CONSTANT PRESSURE.
ROTARY GEAR PUMP CAN ROTATE IN EITHER DIRECTION
COMPENSATION NEEDLE VALVE (ADJUSTABLE)
FULL LOAD
HALF LOAD
STOP
SERVOMOTOR OR POWER CYLINDER
OIL SUMP TANK D-1
PUMP SUCTION

FIG. 2-3

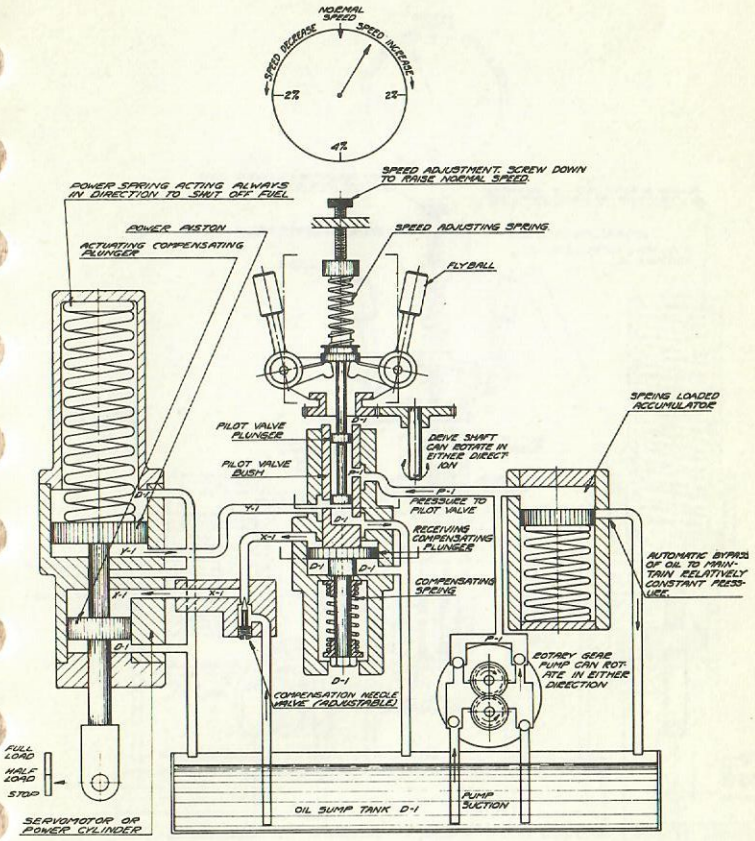

NORMAL SPEED
SPEED DECREASE
SPEED INCREASE
2%
2%
4%
POWER SPRING ACTING ALWAYS IN DIRECTION TO SHUT OFF FUEL
SPEED ADJUSTMENT. SCREW DOWN TO RAISE NORMAL SPEED
POWER PISTON
ACTUATING COMPENSATING PLUNGER
SPEED ADJUSTING SPRING
FLYBALL
PILOT VALVE PLUNGER
PILOT VALVE BUSH
D-1
DRIVE SHAFT CAN ROTATE IN EITHER DIRECTION
SPRING LOADED ACCUMULATOR
P-1
PRESSURE TO PILOT VALVE
Y-1
X-1
RECEIVING COMPENSATING PLUNGER
COMPENSATING SPRING
AUTOMATIC BYPASS OF OIL TO MAINTAIN RELATIVLY CONSTANT PRESSURE.
ROTARY GEAR PUMP CAN ROTATE IN EITHER DIRECTION
COMPENSATION NEEDLE VALVE (ADJUSTABLE)
FULL LOAD
HALF LOAD
STOP
SERVOMOTOR OR POWER CYLINDER
OIL SUMP TANK D-1
PUMP SUCTION

FIG. 3-3

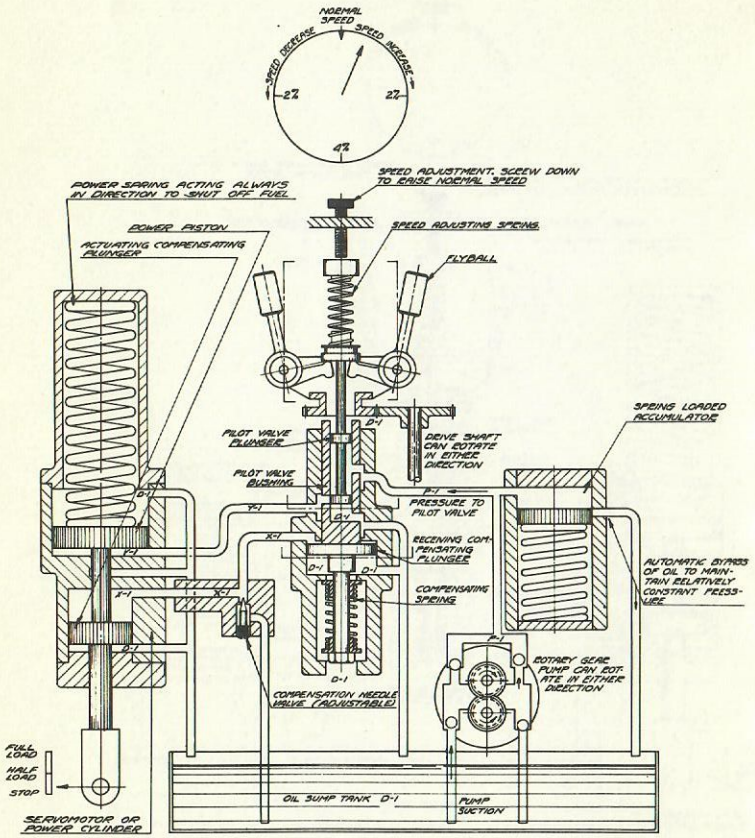

NORMAL SPEED
SPEED DECREASE
SPEED INCREASE
2%
2%
4%
POWER SPRING ACTING ALWAYS IN DIRECTION TO SHUT OFF FUEL
SPEED ADJUSTMENT. SCREW DOWN TO RAISE NORMAL SPEED
POWER PISTON
ACTUATING COMPENSATING PLUNGER
SPEED ADJUSTING SPRING
FLYBALL
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
DRIVE SHAFT CAN ROTATE IN EITHER DIRECTION
SPRING LOADED ACCUMULATOR
PRESSURE TO PILOT VALVE
RECEIVING COMPENSATING PLUNGER
COMPENSATING SPRING
AUTOMATIC BYPASS OF OIL TO MAINTAIN RELATIVELY CONSTANT PRESSURE
ROTARY GEAR PUMP CAN ROTATE IN EITHER DIRECTION
COMPENSATION NEEDLE VALVE (ADJUSTABLE)
FULL LOAD
HALF LOAD STOP
SERVOMOTOR OR POWER CYLINDER
OIL SUMP TANK D-1
PUMP SUCTION

FIG. 4-3

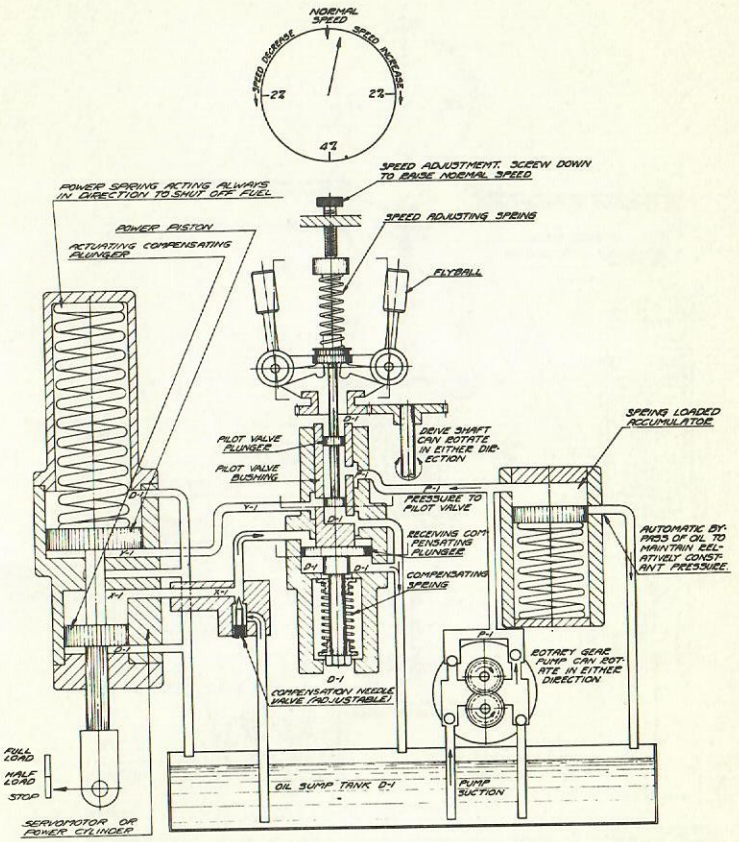

NORMAL SPEED
SPEED DECREASE
SPEED INCREASE
2%
2%
4%
POWER SPRING ACTING ALWAYS IN DIRECTION TO SHUT OFF FUEL
SPEED ADJUSTMENT. SCREW DOWN TO RAISE NORMAL SPEED
POWER PISTON
ACTUATING COMPENSATING PLUNGER
SPEED ADJUSTING SPRING
FLYBALL
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
DRIVE SHAFT CAN ROTATE IN EITHER DIRECTION
SPRING LOADED ACCUMULATOR
PRESSURE TO PILOT VALVE
RECEIVING COMPENSATING PLUNGER
COMPENSATING SPRING
AUTOMATIC BYPASS OF OIL TO MAINTAIN RELATIVELY CONSTANT PRESSURE
ROTARY GEAR PUMP CAN ROTATE IN EITHER DIRECTION
COMPENSATION NEEDLE VALVE (ADJUSTABLE)
FULL LOAD
HALF LOAD STOP
SERVOMOTOR OR POWER CYLINDER
OIL SUMP TANK D-1
PUMP SUCTION

FIG. 5-3

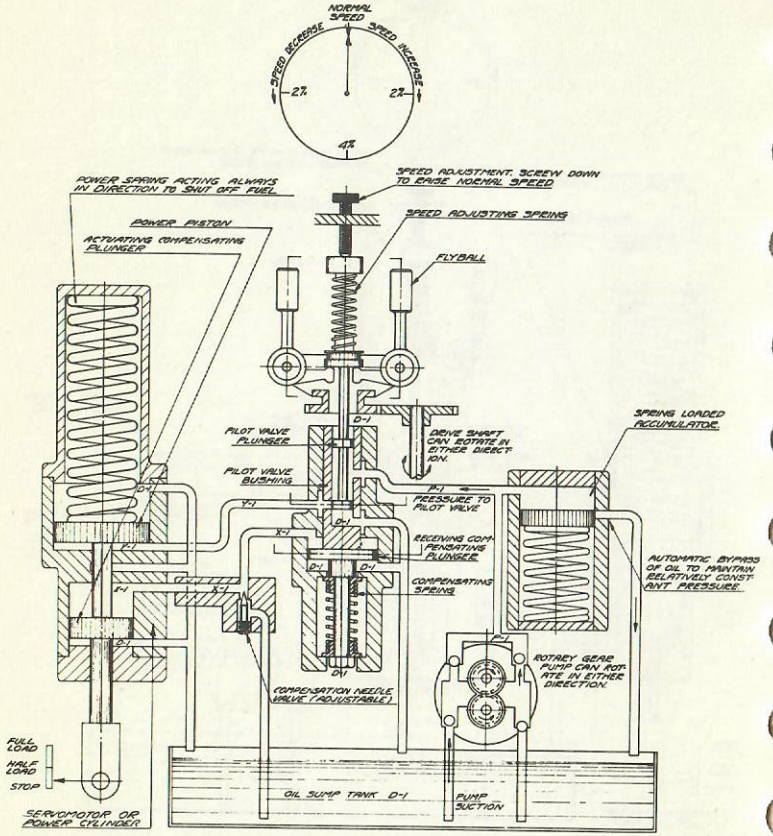

NORMAL SPEED
SPEED DECREASE
SPEED INCREASE
2%
2%
4%
POWER SPRING ACTING ALWAYS IN DIRECTION TO SHUT OFF FUEL
SPEED ADJUSTMENT. SCREW DOWN TO RAISE NORMAL SPEED
POWER PISTON
SPEED ADJUSTING SPRING
ACTIVATING COMPENSATING PLUNGER
FLYBALL
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
DRIVE SHAFT CAN ROTATE IN EITHER DIRECTION.
SPRING LOADED ACCUMULATOR
PRESSURE TO PILOT VALVE
RECEIVING COMPENSATING PLUNGER
COMPENSATING SPRING
AUTOMATIC BYPASS OF OIL TO MAINTAIN RELATIVELY CONSTANT PRESSURE
ROTREY GEAR PUMP CAN ROTATE IN EITHER DIRECTION.
COMPENSATION NEEDLE VALVE (ADJUSTABLE)
FULL LOAD
HALF LOAD STOP
SERVOMOTOR OR POWER CYLINDER
OIL SUMP TANK D-1
PUMP SUCTION

FIG. 6-3

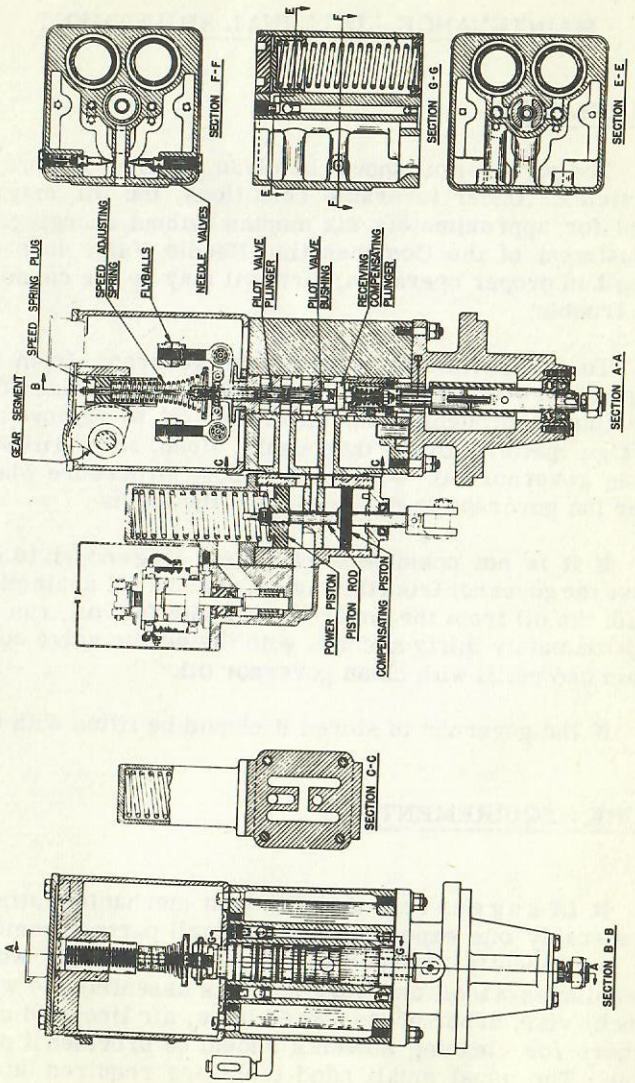

SECTION F-F
SECTION G-G
SECTION E-E
SPEED ADJUSTING SPRING
FLYBALLS
NEEDLE VALVES
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
RECEIVING COMPENSATING PLUNGER
SPEED SPRING PLUG
GEAR SEGMENT
SECTION A-A
POWER PISTON
PISTON ROD
COMPENSATING PISTON
SECTION C-C
SECTION B-B

FIG. 7-3

MAINTENANCE - INTERNAL ADJUSTMENT

OIL CHANGES

The governor oil should be clean and free of foreign particles. Under favorable conditions, the oil may be used for approximately six months without changing. If adjustment of the Compensating Needle Valve does not result in proper operation, dirty oil may be the cause of the trouble.

To change the oil, remove the governor from the engine, take off the cover, drain by turning upside down and flush thoroughly with clean fuel oil to remove any foreign matter. Drain thoroughly, flush, and refill with clean governor oil. Follow the above procedure whenever the governor is removed from the engine.

If it is not possible to shut down long enough to remove the governor from the engine, remove oil drain plug, drain the oil from the governor, fill with fuel oil, run for approximately thirty seconds with the needle valve open, drain and refill with clean governor oil.

If the governor is stored it should be filled with oil.

WORK REQUIREMENTS

It is suggested that the best mechanic available (preferably one experienced with small parts assembly) be permanently assigned to all governor repair work. Cleanliness of tools and work space is essential. A work bench, vise, arbor press, speed lathe, air line, and containers for cleaning solvents should be provided if possible. The usual small hand tools are required and a few special Woodward Governor tools are desirable if subassemblies are to be disassembled.

DISASSEMBLY OF GOVERNOR INTO SUBASSEMBLIES

A. Cover

1. Remove four screws and lift off.

B. Column

1. Unscrew four column retaining screws in inside corners of column and lift off column. Screws may be left in place.

C. Rotating Sleeve

1. Unscrew two flathead screws in retainer plate and remove screws, Fig. 8-3.

2. Raise ballhead carefully and remove two laminated washers under retainer plate to avoid dropping them into the governor sump, Fig. 9-3.

3. Remove rotating sleeve assembly from governor.

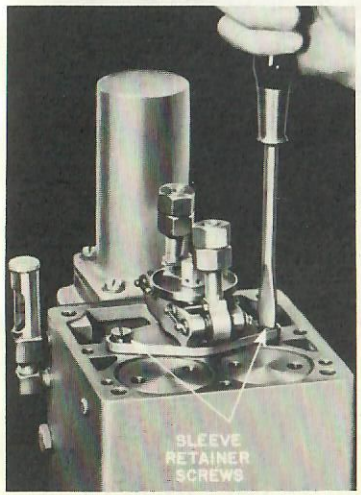


FIG. 8-3

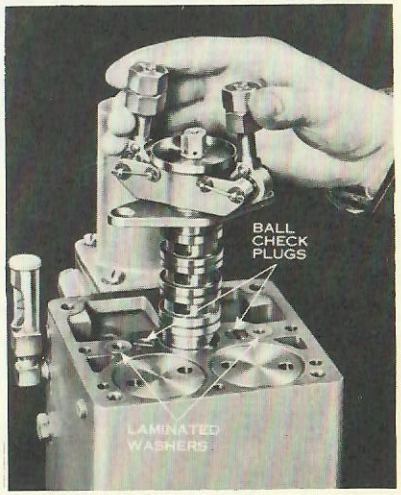


FIG. 9-3

D. Servomotor

1. Remove four stud nuts.

2. Remove servomotor. It may be necessary to tap with a plastic hammer to break loose from gasket.

NOTE: If the governor has an adapter pad between the servomotor and power case be sure to mark it prior to removal so it will be replaced in the correct position.

E. Power Case and Base

1. Remove eight locknuts and eight stud nuts. Pull off base, Fig. 10-3. Drive against edge of base with plastic hammer as shown to break loose gasket. Pull evenly to clear dowel pins.

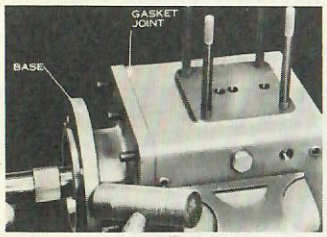


FIG. 10-3

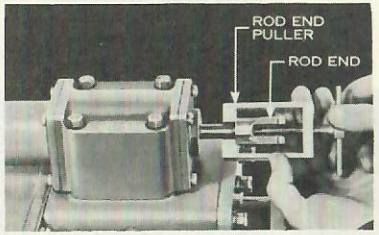


FIG. 11-3

OIL SEALS

When it becomes necessary to add oil to the governor too frequently, the oil seals should be replaced.

DRIVE SHAFT OIL SEAL

1. See instructions on Drive Shaft Repair, Page No. 325.

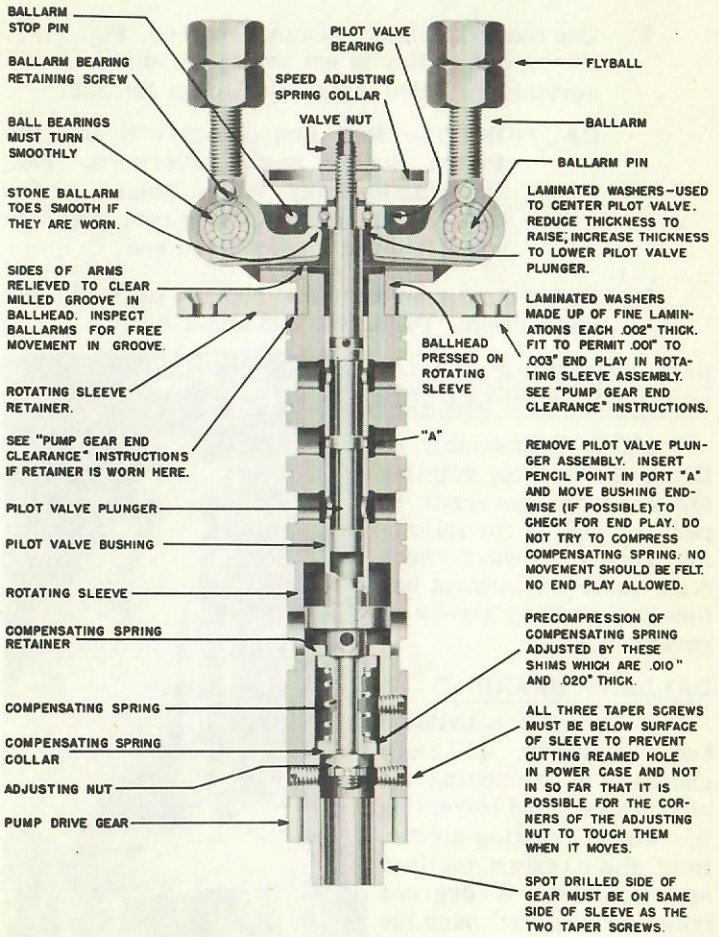

BALLARM STOP PIN
BALLARM BEARING RETAINING SCREW
BALL BEARINGS MUST TURN SMOOTHLY
STONE BALLARM TOES SMOOTH IF THEY ARE WORN.
SIDES OF ARMS RELIEVED TO CLEAR MILLED GROOVE IN BALLHEAD. INSPECT BALLARMS FOR FREE MOVEMENT IN GROOVE.
ROTATING SLEEVE RETAINER.
SEE "PUMP GEAR END CLEARANCE" INSTRUCTIONS IF RETAINER IS WORN HERE.
PILOT VALVE PLUNGER
PILOT VALVE BUSHING
ROTATING SLEEVE
COMPENSATING SPRING RETAINER
COMPENSATING SPRING
COMPENSATING SPRING COLLAR
ADJUSTING NUT
PUMP DRIVE GEAR
PILOT VALVE BEARING
SPEED ADJUSTING SPRING COLLAR
VALVE NUT
BALLHEAD PRESSED ON ROTATING SLEEVE
"A"
FLYBALL
BALLARM
BALLARM PIN
LAMINATED WASHERS—USED TO CENTER PILOT VALVE. REDUCE THICKNESS TO RAISE; INCREASE THICKNESS TO LOWER PILOT VALVE PLUNGER.
LAMINATED WASHERS MADE UP OF FINE LAMINATIONS EACH .002" THICK. FIT TO PERMIT .001" TO .003" END PLAY IN ROTATING SLEEVE ASSEMBLY. SEE "PUMP GEAR END CLEARANCE" INSTRUCTIONS.
REMOVE PILOT VALVE PLUNGER ASSEMBLY. INSERT PENCIL POINT IN PORT "A" AND MOVE BUSHING ENDWISE (IF POSSIBLE) TO CHECK FOR END PLAY. DO NOT TRY TO COMPRESS COMPENSATING SPRING. NO MOVEMENT SHOULD BE FELT. NO END PLAY ALLOWED.
PRECOMPRESSION OF COMPENSATING SPRING ADJUSTED BY THESE SHIMS WHICH ARE .010" AND .020" THICK.
ALL THREE TAPER SCREWS MUST BE BELOW SURFACE OF SLEEVE TO PREVENT CUTTING REAMED HOLE IN POWER CASE AND NOT IN SO FAR THAT IT IS POSSIBLE FOR THE CORNERS OF THE ADJUSTING NUT TO TOUCH THEM WHEN IT MOVES.
SPOT DRILLED SIDE OF GEAR MUST BE ON SAME SIDE OF SLEEVE AS THE TWO TAPER SCREWS.

FIG. 12-3

PISTON ROD OIL SEAL

1. Remove taper pin in rod end. Use care not to bend piston rod.
2. Use rod end puller to remove rod end, Fig. 11-3. If rod end puller is not available, disassemble servomotor. See instruction, page No. 323.

   CAUTION: The Rod End is screwed onto the Piston Rod in some governors. This construction may be recognized by the flats milled on the piston rod. Use two wrenches and unscrew rod end.
3. Remove cylinder head and replace oil seal. See instructions, Page. No. 323 and 324.

ROTATING SLEEVE ADJUSTMENT AND REPAIR

Make disassembly A, B, and C removing rotating sleeve from governor to perform any of the following work. Always check pilot valve adjustment before reinstalling sleeve in governor.

BALLARM BEARINGS

Action of the ballarm bearing may be quickly checked by removing the pilot valve and inverting the whole rotating sleeve. Hold the sleeve inclined approximately 5 degrees from vertical and push the flyball outward as shown in Fig. 13-3. It should move outward freely and drop back freely when released.

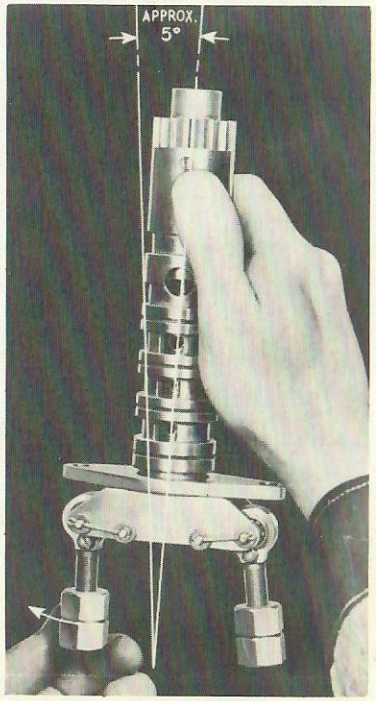


FIG. 13-3

Wear of the bearings may be checked by moving the ballarms sidewise as shown in Fig. 14-3. Movement of 1/64 of an inch may be expected from new bearings. Bearings may be used until the movement reaches 1/16 inch.

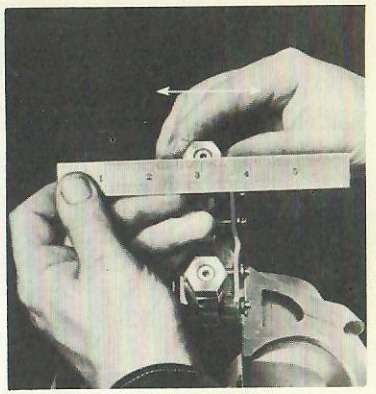


FIG. 14-3

If necessary to correct roughness or replace bearings continue with the following instructions:

1. Remove cotters and ballarm pins, using care not to bend pins.
2. Remove ballarm bearing screw and nut. The nut is prick punched to prevent loosening but can be removed by using force. Push out bearings.
3. Turn bearings between fingers testing for roughness.
4. If slightly rough or worn excessively, replace with new bearings.
5. If bearings do not go into ballarm with finger push, it indicates that the ballarm bearing bore has distorted to an oval shape. Ream out tight sides of the hole carefully with three cornered scraper until the bearing pushes in without distorting the outer race of the bearing. Replace retainer screws.

BALLARM TOES

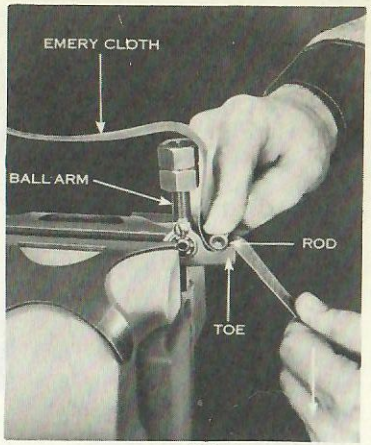


FIG. 15-3

The ballarm toes must be smoothly finished to allow them to slide on the face of the pilot valve plunger bearing. If there is any indication of wear or grooving, refinish them by hand with fine emery cloth as shown in Fig. 15-3.

Install new ballarms if worn excessively. The flyballs should be set in same position as they were on the old ballarms. If in doubt set the top nut flush with the end of the ballarm.

BALLARM PINS

The ballarm pins should fit the bearing hole snugly but a slip fit is satisfactory. If the pins are worn they may be interchanged with the ballarm stop pins.

PILOT VALVE PLUNGER BEARING

The face of the outer race of the pilot valve bearing where it contacts the ballarm toes must be perfectly flat. If grooved it may be turned to use the opposite face or it may be replaced with a new bearing. If worn internally, the bearing should be replaced.

PILOT VALVE BUSHING

1. Remove three taper screws and pull out pump drive gear, Fig. 12-3.

2. Push out the pilot valve bushing assembly.

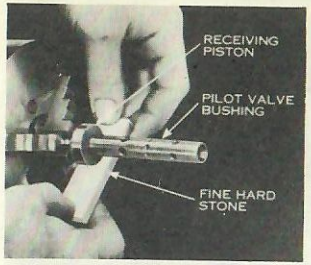


FIG. 16-3

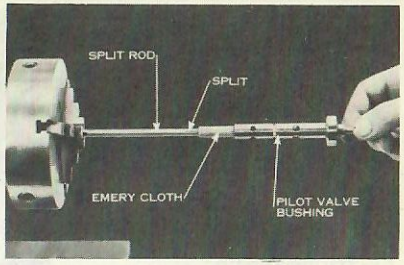


FIG. 17-3

The pilot valve bushing must move freely in the rotating sleeve without sticking or catching. The outside of the bushing may be polished in a speed lathe if necessary as shown in Fig. 16-3. Use a fine, hard stone. Do not break sharp corners of the large diameter. Polish the threaded end lengthwise to remove sharp corners on thread and polish stem.

The pilot valve plunger must move freely in the pilot valve bushing. To polish the inside of the bushing, use a 1/4" diameter split rod wound with fine emery cloth and use in a speed lathe as shown in Fig. 17-3. Do not break the inside edge of the holes through the bushing.

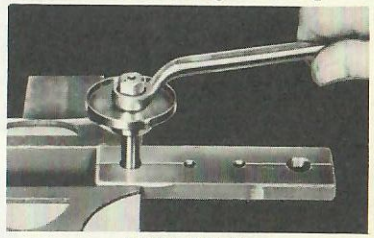


FIG. 18-3

PILOT VALVE PLUNGER

The pilot valve plunger must be handled carefully avoid nicking the sharp edges of the lands. It must move freely in the pilot valve bushing without sticking or catching. Clamp the plunger in a split strap as shown in Fig. 18-3 or in a vise as shown in Fig. 19-3 to remove the pilot valve nut.

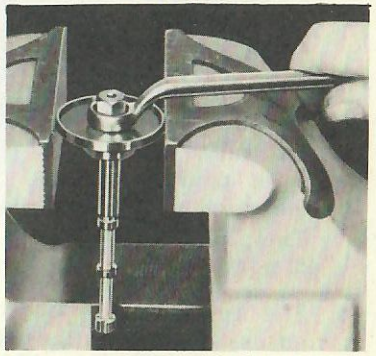


FIG. 19-3

Polish the plunger with a fine hard stone if necessary as shown in Fig. 20-3. Do not break the sharp corners of the control land.

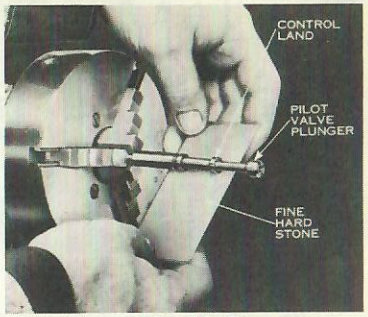


FIG. 20-3

PILOT VALVE ADJUSTMENT

The pilot valve adjustment should be checked after doing any work on ballarms, pilot valve plunger, or pilot valve bushing, and whenever the rotating sleeve is removed from the governor for other reasons.

1. Hold the rotating sleeve upright with the pilot valve plunger assembly in place.

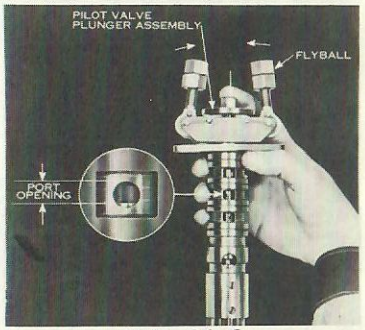


FIG. 21-3

2. Push down on the pilot valve plunger as shown in Fig. 21-3. This will move the flyballs to inner position. Note amount of port opening.

3. Continue holding down on pilot valve plunger and move flyballs to outer position raising the pilot valve land, Fig. 22-3. Note amt. of port opening.

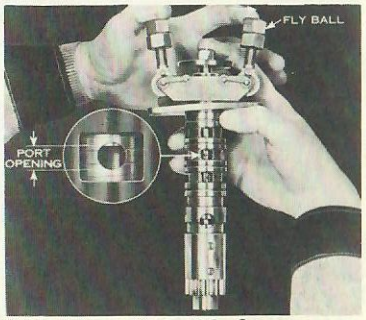


FIG. 22-3

4. The amount of port opening for inner and outer positions of the flyballs should be the same and should be correct to within .005".

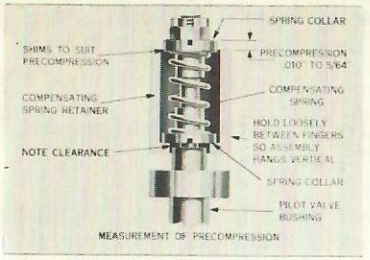


FIG. 23-3

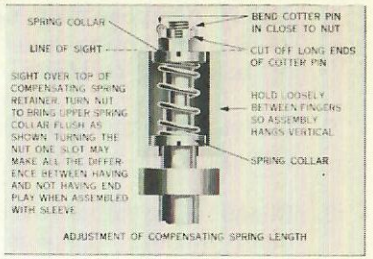

SPRING COLLAR
LINE OF SIGHT
SIGHT OVER TOP OF COMPENSATING SPRING RETAINER. TURN NUT TO BRING UPPER SPRING COLLAR FLUSH AS SHOWN. TURNING THE NUT ONE SLOT MAY MAKE ALL THE DIFFERENCE BETWEEN HAVING AND NOT HAVING END PLAY WHEN ASSEMBLED WITH SLEEVE
BEND COTTER PIN IN CLOSE TO NUT
CUT OFF LONG ENDS OF COTTER PIN
HOLD LOOSELY BETWEEN FINGERS SO ASSEMBLY HANGS VERTICAL
SPRING COLLAR
ADJUSTMENT OF COMPENSATING SPRING LENGTH

FIG. 24-3

5. If the pilot valve plunger needs to be raised to equalize the openings, reduce the thickness of the laminated washers between the pilot valve bearing and the shoulder of the pilot valve plunger. If the plunger needs to be lowered, add the necessary laminations to the washer to increase its thickness. Fig. 12-3.

COMPENSATING SPRING ADJUSTMENT

1. Make disassembly A, B, and C, removing rotating sleeve from governor.
2. Remove pilot valve plunger assembly. See Fig. 12-3.
3. Remove three taper screws.
4. Pull out pump drive gear and pilot valve bushing assemblies.
5. Remove cotter and back off adjusting castle nut to release spring load, Fig. 23-3.
6. Change precompression, if necessary.

This precompression may vary from .010" to 5/64" depending upon characteristics of engine and load. To eliminate a hunt, remove shims to reduce precompression. To eliminate a surge, add shims to increase precompression. It is essential to make the following adjustment regardless of the amount of precompression obtained in instruction No. 6, above.

Adjust compensating spring length as shown in Fig. 24-3. The collar must be exactly flush with the top of the spring retainer.

7. Insert 1/16" cotter pin through castle nut and secure. Cut off ends as shown in Fig. 24-3.

8. Reassemble with sleeve and pump drive gear. Tighten taper screws. Inspect ends of screws to be certain they do not project outside of sleeve. File off burrs at slots if necessary.

9. Remove pilot valve if in bushing and check for end play or lost motion of bushing by inserting pencil point in port "A" Fig. 12-3, and attempt to move it endwise with light force in both directions, Fig. 25-3. No end play or lost motion allowed.

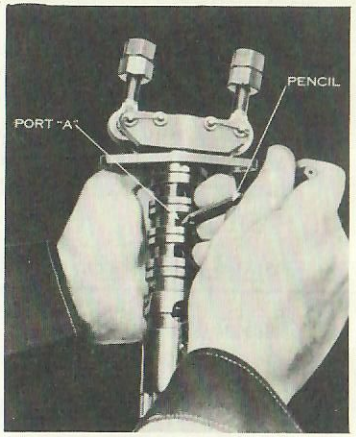


FIG. 25-3

10. If lost motion or end play is detected, it indicates the nut is incorrectly adjusted and should be readjusted as shown in Fig. 24-3. The upper spring collar must be exactly flush with the end of the spring retainer.

CHECK VALVES

Low oil pressure may indicate pressure leakage at the check valves. The valves should be reseated each time the governor is overhauled and when oil pressure is low. See pump gear end clearance instructions, pg. 328.

1. Make disassemblies A, B, C, and D.

2. Remove the ball check plugs. See top view of power case, Fig. 9-3.

3. Invert governor removing the four steel balls.

4. Flush power case with light fuel oil and blow out with clean air hose.

5. Set governor upright and drop one of the 1/4" balls into each hole.

6. Place 1/4" rod on top of each ball and tap ball into the soft metal seat. Fig. 26-3.

7. Drop 3/8" balls into each hole.

8. Tap into seat with rod.

9. Invert governor removing the balls.

10. Inspect check valve bushings at pump bore to be certain bushings are not restricting oil flow. See Fig. 26-3. If bushing is too low drive it back up.

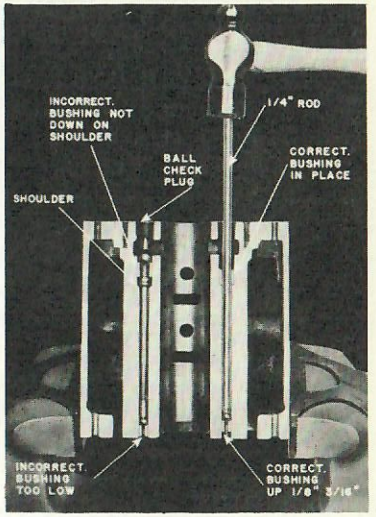


FIG. 26-3

11. Inspect balls for flat spots and cracks. Replace in holes.

12. Replace ball check plugs.

SERVOMOTOR

Disassembly of the servomotor will mainly be required.

a. To permit cleaning and polishing of parts.

b. Replacing a bent piston rod; or

c. To replace oil seal. See page No. 316 for possible short cut to oil seal replacement without full disassembly.

1. Make disassembly D, page 314.

2. Remove spring guard. Place servomotor in arbor press. Hold guard in place with press while removing four screws. Steady spring guard with one hand while gradually releasing press. See Fig. 27-3. The guard compresses a powerful spring. Care must be used in its removal.

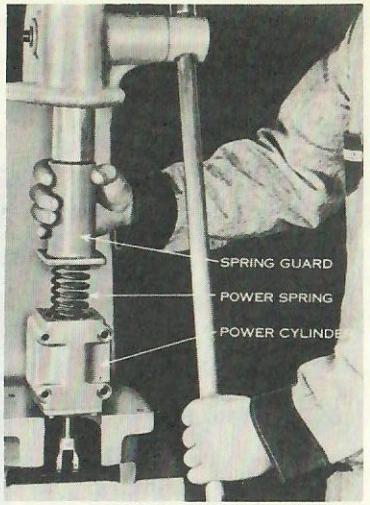


FIG. 27-3

3. Remove four screws holding cylinder head.

4. Place power cylinder in vise, remove cotter and nut holding piston rod, Fig. 28-3.

5. Remove piston rod, Fig. 29-3.

6. Press piston rod out of compensating piston, Fig. 30-3.

7. To replace oil seal pry out old seal from cylinder head and press in new seal, Fig. 31-3.

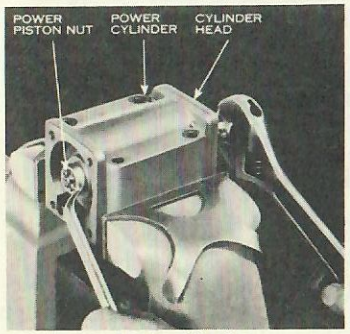


FIG. 28-3

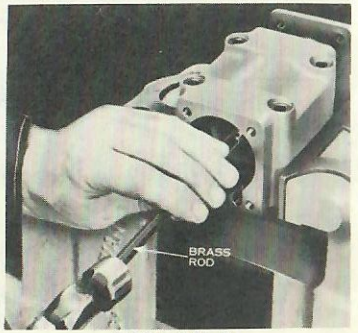


FIG. 29-3

8. Reassembly. Reverse the preceding steps.

   a. Use care in inserting piston rod in cylinder head to prevent damage to oil seal lip. If oil seal inserter is not available, use thin shim stock to protect seal.

   b. In pressing compensating piston on piston rod see that piston fits tight to shoulder on rod. Use care not to bend rod.

   c. After replacing power piston and nut, pistons must work freely when power cylinder is bolted to power case. Make this test without spring and guard. If rotating sleeve is in power case remove the pilot valve plunger assembly. Remove power cylinder from power case and complete servomotor assembly.

DRIVE SHAFT DISASSEMBLY AND REPAIR

1. Remove lockwire.

2. Remove four cap screws

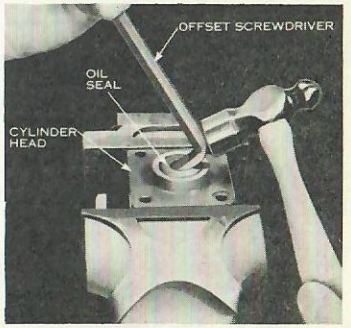


FIG. 31-3

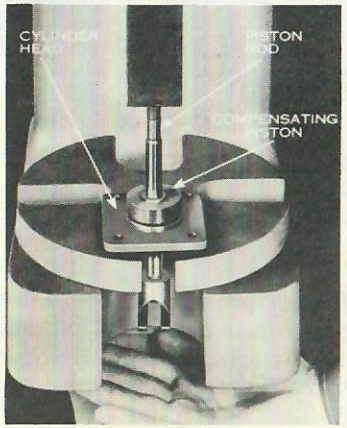


FIG. 30-3

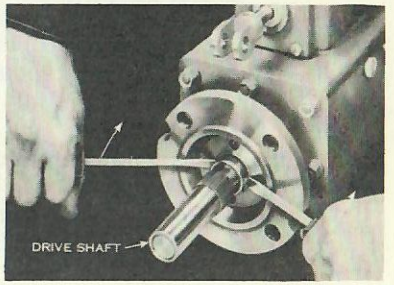


FIG. 32-3

3. Remove drive shaft assembly from bore in base. See Fig. 32-3.

4. Remove snap ring, Fig. 33-3.

5. Press drive shaft out of bearing. See Fig. 34-3.

6. Remove bearing retainer.

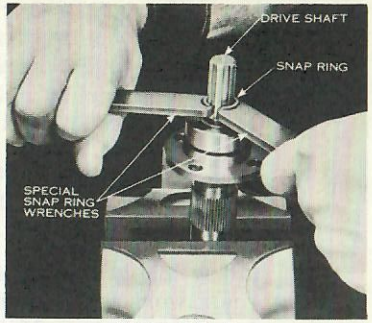


FIG. 33-3

7. Replace oil seal in bearing retainer if worn. Use care not to damage lip of seal when inserting shaft, (use inserter).

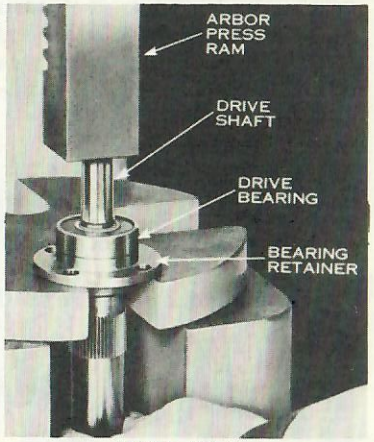


FIG. 34-3

8. Inspect drive bearing for wear and free rotation. Replace if it shows any sign of wear.

9. It will not be necessary to disassemble the spring drive unless governor has had several years operation and is being completely overhauled. In this case spring drive laminations should be inspected for wear or possible breakage.

   To disassemble drive out taper pin and pull off drive sleeve. Polish out any grooves in alignment pin and sleeve bore in which laminations might catch. Remove all burrs and sharp corners from new laminations.

10. Reassemble.

ASSEMBLY INSTRUCTIONS

Caution: Do not drop or rest governor on its drive shaft.

A. Assembly of Power Case to Base

1. Clean off machined surfaces of base and power case.

2. Lay special .005" thick vellumoid gasket on flat surface and paint with thinned shellac on power case side.

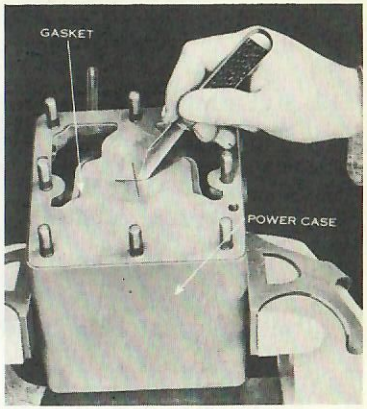


FIG. 35-3

3. Place on power case.

4. Slit gasket with knife as shown in Fig. 35-3.

5. Set base on power case to press gasket flat and allow shellac to dry. Use four nuts.

6. Remove base and cut out gasket at gear pockets with sharp knife. Use sliding downward cut as shown in Fig. 36-3. Do not tap out gasket with hammer.

7. Cut strip out of gasket at oil groove. See Fig. 36-3.

8. Cut openings at check valve bushings as shown in Fig. 36-3.

9. Place idler pump gear in gear pocket of power case.

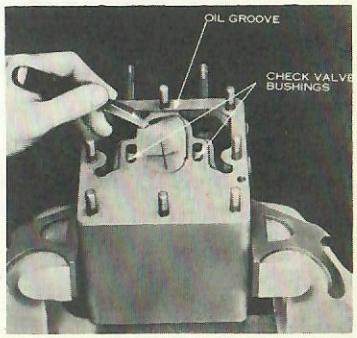


FIG. 36-3

10. Place base on case. Place thick washers and nuts on studs and finger tighten.

11. Put rotating sleeve in power case and check alignment or use special **aligning tool.**

12. Strike various corners of base with babbitt hammer as shown in Fig. 37-3 until the rotating sleeve turns freely.

13. Secure nuts and lock with special lock nuts.

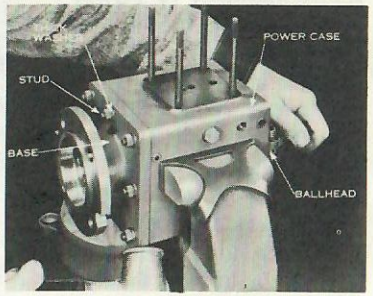


FIG. 37-3

B. Pump Gear End Clearance and Installation of Rotating Sleeve

Low oil pressure may indicate pressure leakage at the lower end of the rotating sleeve at the pump gear face. Excessive end clearance will reduce pump capacity. If there is not sufficient end clearance, excessive wear and possibly seizure will result. Pump gear end clearance is determined by the thickness of laminated washers under rotating sleeve retainer. Clearance should be from .001" to .003". See Fig. 9-3 and 12-3.

1. Remove one lamination (.002") from washer under each end of retainer.

2. Replace retainer and screws. Tighten screws and turn sleeve. If it turns freely, repeat No. 1 continuing until the sleeve turns hard.

3. Put back one lamination (.002") under each end to get minimum clearance at the pump gear face.

4. Secure retainer with screws, Fig. 8-3.

If the laminated washers have been completely removed and the sleeve **will still turn freely the retainer must be replaced.**

1. Remove sleeve from power case.

2. Press rotating sleeve out of ballhead as shown in Fig. 38-3.

3. Reassemble using new retainer and new laminated washers. The old retainer (which is surface hardened) may be reused temporarily if the work side is surface ground to remove the wear groove.

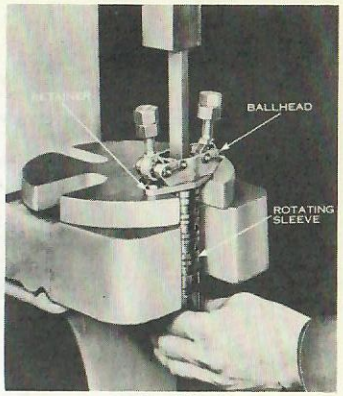


FIG. 38-3

4. Adjust for correct pump gear end clearance.

C. Assemble servomotor to power case. Too much force in tightening nuts will distort power cylinder and bind pistons. If torque wrench is available set nut to 200 pounds.

D. Insert pilot valve plunger assembly. Replace speed spring. Assemble column to power case.

Check to see that speeder spring is properly seated.

E. Flush out governor with fuel oil. Fill to the correct lever with governor oil.

Replace cover.

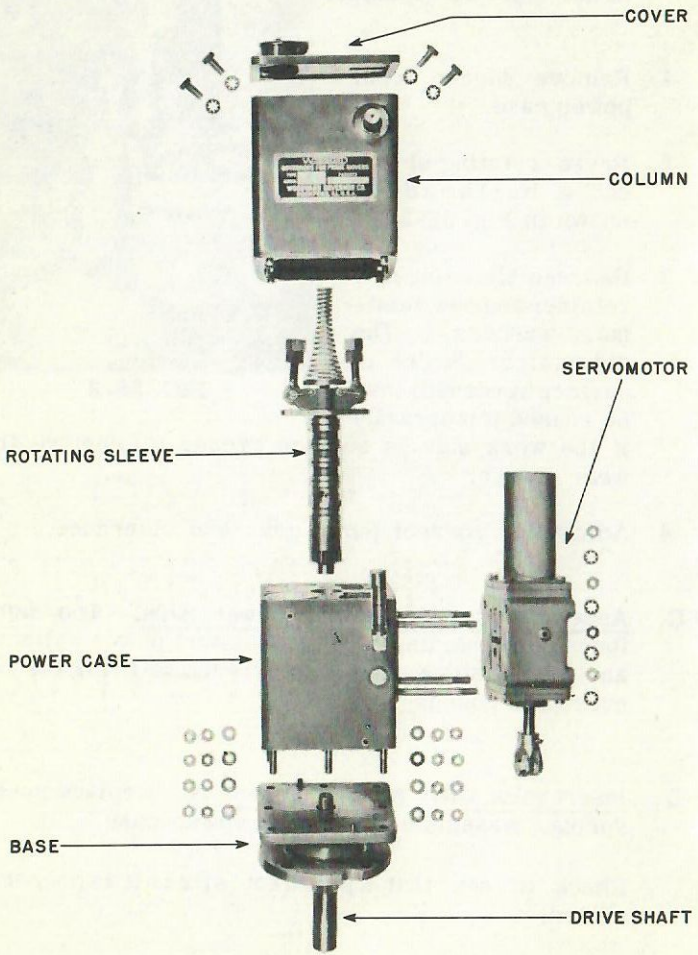


FIG. 39-3

FUEL INJECTION PUMP AND GOVERNOR DRIVE

Description

The fuel injection pump and governor drive assembly, mounted on the fuel pump side of the main frame, is composed of a number of sub-assemblies by means of which the engine is controlled. The drive shaft assembly of the unit is geared to the crankshaft, through the main gear train, at a speed reduction of 2-1.

The principal sub-assemblies, include the fuel injection pumps, fuel pump control linkage, emergency stop mechanism and the speed regulating governor, Fig. 40-3.

Fuel Pumps

The fuel injection pumps are mounted on the top of the main fuel pump casing and are reciprocated by cams of the fuel injection pump camshaft which is incorporated in the drive shaft assembly. These cams act through individual crosshead assemblies which serve the respective pumps.

Control Linkage

The fuel pump control linkage, which consists of a number of levers, rods and suitable links, transmits motion from the governor to the control racks of the injection pumps.

Emergency Stop Mechanism

The emergency stop mechanism is another incorporated feature provided for the purpose of rapidly cutting out the fuel injection pumps when an emergency arises which indicates the necessity of an immediate stop. Tripping is accomplished manually by pulling the emergency

stop handle which is located on the top of the after section of the governor drive casing. The resulting action is fully described under "Engine Overspeed Trip".

Governor Drive

The governor drive gear is mounted on the forward end of the fuel pump camshaft driving the governor through a pair of bevelled gears. If it is necessary to remove the governor drive gear, the entire governor drive can be loosened and lifted out through the top of the fuel pump drive casing as a unit. Remove the cover on the governor end of the fuel pump drive casing and remove the entire camshaft and drive shaft as described in the next paragraph. If it is ever necessary to dismantle the governor drive gear and cutout weights be sure the oil holes match when replacing the parts or the gear will not be properly lubricated when placed in operation.

Fuel Pump Drive

To remove the fuel pump drive, dismantle the water pump, fuel pump drive and camshaft end bearings, which are in the gear case cover and the upper gear casing. Remove the end cover at the governor end and the governor drive assembly from the fuel pump drive casing. Pull the emergency trip lever and make certain all the fuel pump crossheads are in the cutout position by turning the engine until all the cutout plungers have moved in.

Remove the nut from the end of the shaft and drive the shaft out of the gear with a few sharp blows with a soft hammer. When the drive shaft is being moved back, care is to be taken to prevent any damage to the drive shaft and camshaft bearings. Lift out the fuel pump gear carefully without damaging the thrust washers after the shaft has been slid back through the fuel pump drive casing.

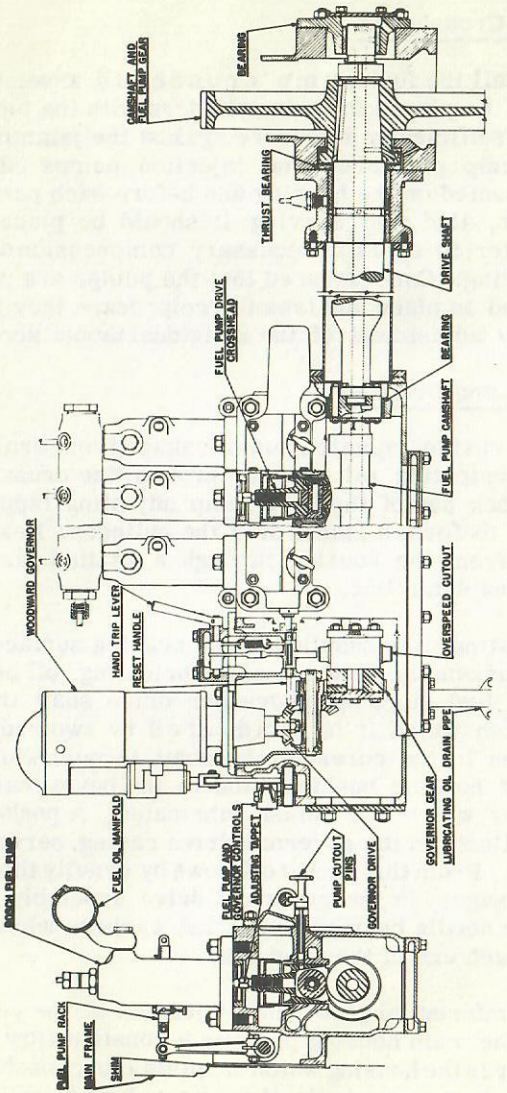


FIG. 40-3
FUEL PUMP AND GOVERNOR DRIVE

Fuel Pump Crossheads

To install the fuel pump crosshead assemblies they should be placed in their cylinders with the tappets backed off sufficiently to insure against the jamming of the fuel pump plungers. The injection pumps should then be mounted on the housing and before each pump is bolted down, the cam serving it should be placed on bottom center to avoid unnecessary compression of the plunger spring. Once assured that the pumps are properly secured in place and free to reciprocate, they must be timed by adjustment of the individual tappet screws.

Lubrication and Drainage

To prevent fuel injection pump leakage from draining into the lubricating oil system through the crosshead bore, the lock nut of the fuel pump adjusting tappet is cap-shaped to form a shield over the cylinder. Leakage is drained from the housing through a drilled passage and a suitable drain line.

Lubricating oil is supplied to the bearing surfaces of the entire assembly by the main lubricating oil pump, through the fuel pump and governor drive shaft thrust bearing, from which it is conducted by two radially drilled holes to the cores of the shaft through which it flows to the housing bushings and to the bevel gears in the governor which are splash lubricated. A pocket, in which oil collects in the governor drive casing, serves as a reservoir. From this pocket oil flows by gravity through drilled passages in the governor drive assembly gear shaft to the needle bearing and thrust washers which are located at each end of the spur gear.

A circumferential groove in the journal of the center bushing of the main housing permits a constant flow to a cored header in the housing which supplies the crossheads individually through ports in the crosshead cylinder walls. The crosshead body and the cam roller pin are suitably drilled to provide a passage to the cam roller.

Lubricating oil collecting on the crosshead body top is drained off through holes in the head. Drainage from the assembly to the crankcase is carried by a special drain fitting.

Fuel oil is fed to the injection pumps by the fuel oil booster pump, through the supply line, fuel filter assembly and the injection pump manifold. The hollow inlet screws which secure the manifold connections to the injection pumps, also vurnish passage for the oil to the plunger chambers. Leakage at the manifold connections is prevented by two solid copper gaskets which should always be annealed before reinstallation.

FUEL PUMP CONTROL LINKAGE

The amount of fuel oil delivered to the cylinders by the injection pumps is controlled by the Woodward Governor. Adjustment of the governor is made by turning the governor terminal shaft, which is done by opening the engineer's throttle. The governor will automatically increase or decrease the amount of fuel injected by changing the setting of the control rods (racks) of the injection pumps to compensate for changes in the load applied to the engine.

When the throttle is open, requiring an increase in Diesel engine speed, the power piston rod of the governor will move upward causing a corresponding movement of the short link and operating lever of the governor linkage. As the operating lever is pinned to the control shaft, the shaft is forced to rotate in the "increased fuel direction". Motion is transmitted from the control shaft to the fuel pump control racks by individual levers which, clamped and dowelled to the control shaft, extend upward to the pump racks. The upper ends of these levers are yoke-shaped and are fitted with pins which are drilled and tapped to accommodate the adjusting screws which connect the levers to the fuel pump control racks. The control rack ends of these adjusting screws are in the form of clevises which are fitted to the racks by means

of link pins. When the governor acts to increase the amount of fuel being injected by the fuel pumps, the control racks of the pump will move outward, away from the engine. Stop collars, dowelled to the fuel control racks of fuel pumps limit the travel of the control linkage in the "increased fuel" direction.

When a decrease in the amount of fuel injected is demanded the power piston rod of the governor will move downward, causing a corresponding movement of the short link and operating lever of the governor linkage.

As the latter lever is pinned to the fuel pump control shaft, the shaft will be forced to rotate in the "decreased fuel" direction. From this point on the movement of the fuel pump control linkage will be the direct opposite of that described in the foregoing paragraph. A multiple-unit engine governor is electro-pneumatically operated by the throttle mechanism but fuel pump control linkage is as described above.

Maintenance

The parts of the linkage should always move freely and with a minimum of lost motion. The small needle bearings and connecting pins should be lubricated with several drops of oil. In the event that there is excess lost motion in the system, the Diesel engine speed will be very erratic and the various pins and bushing should be renewed.

Adjusting Fuel Pump Rack Settings

The correct setting of the fuel pump control racks is 7 MM in shut down position. If the setting is greater than this, difficulty will be experienced with the engine overspeeding when the throttle is closed from full throttle position. The shut down setting should then be corrected by shifting the control shaft which will move all fuel pump racks at the same time. The pump rack settings may also be adjusted individually. The maximum travel

of the fuel pump racks is limited by the dowelled stop and this setting should never be exceeded.

FUEL INJECTION SYSTEM

This system consists of the fuel injection pumps, fuel nozzle pipes and the fuel injection nozzle assemblies.

Each cylinder unit is served by an individual injection pump which when actuated by a cam of the fuel injection pump camshaft, forces the oil delivered by the booster pump to the injection pump chamber into the combustion space of the cylinder which it serves at high pressures.

Discharge from the injection pumps is carried by steel pipes to the nozzles which are designed to withstand very high pressure.

The fuel injection nozzles, through which the oil is forced into the cylinders, are provided for the purpose of atomizing the fuel and to spray it in a definite pattern, to insure complete combustion.

The quantity of fuel delivered per pump stroke is determined by the angular position of the pump plunger.

Adjustments to compensate for changes in load are automatically accomplished by the Woodward speed regulating governor which positions the plungers through the control linkage and suitable mechanism incorporated in the injection pump assembly.

FUEL INJECTION PUMP

The fuel injection pump is of the constant stroke type, the amount of fuel delivered being measured by a helical groove cut in the pump piston which uncovers a by-pass port in different positions as the piston is rotated axially.

One pump unit is provided for each cylinder and all of the pumps are driven from a camshaft connected by a train of gears to the engine crankshaft. The cam noses are solid with a very steep rise which gives constant acceleration and increased penetration of fuel injected into the combustion chamber.

A steel roller follows each cam, the rollers being guided by crossheads in the pump housing. The crossheads carry the tappets which drive the pump plungers. The entire fuel pump drive mechanism is force-feed lubricated.

Each pump may be made inoperative by disengaging the cutout pin from the emergency trip shaft and turning the pin 90 degrees. Then this cutout pin which is spring loaded, will engage the fuel pump crosshead and hold it off the camshaft. To see if the pump is inoperative, look at the timing window in the side of the pump and note if the spring guide is moving up and down. If it is moving, push in on the cutout pin until it engages with the hole in the pump crosshead. To make the pump operative, pull out the pin and engage it in the slot in the shaft.

It will be noticed that all of the cutout pins are normally engaged in the trip shaft which is loaded with a heavy spring and will slide forward, moving all the individual pump cutout pins to the cutout position when the emergency stop-handle is pushed in towards the engine. The same action takes place automatically on operation of the overspeed governor, which is driven off the fuel pump drive shaft.

For resetting instructions and operation data, see the instructions given under "Engine Overspeed Trip".

Each pump consists of a steel barrel and plunger lapped together. This barrel is held in place by means of a lockscrew and gasket located in one side of the pump housing.

A delivery valve and seat is located on top of the pump housing and is held in place by a large holding nut and gasket.

There is no gasket between the face of the delivery valve and the plunger barrel. This is a ground joint and should be carefully guarded against damage if taken out.

The gasket under the delivery valve seat holding nut is the only gasket in the pump and is solid copper.

The operation of the pumps is best explained by means of the five diagrams below:

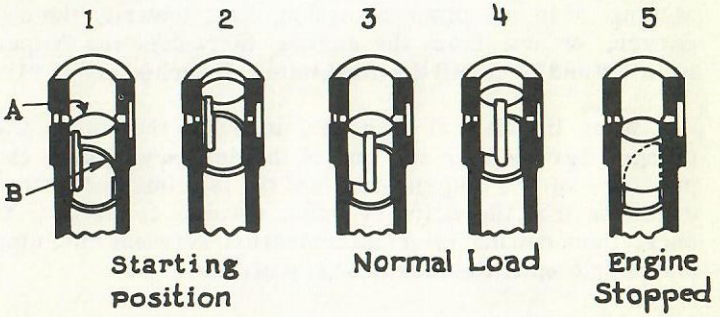


FIG. 41-3
BARREL WITH VARIOUS PLUNGER POSITIONS

When the plunger is at its lowest position, as at 1 and 3, Fig. 41-3, the two ports are in communication with the fuel inlet manifold. A motor-driven booster pump maintains approximately 35 pounds fuel oil pressure in this manifold and the fuel injection pump barrel is charged from this supply.

On the next up, or delivery stroke, the plunger displaces fuel back through the ports until its top edge "A" covers the fuel inlet holes, after which the remaining fuel is forced out through the delivery valve into the feed pipe and to the fuel nozzle. As long as the fuel inlet

ports remain covered the pump will continue to deliver fuel to the nozzle but reference to "2" will show that before the plunger reaches the top of its stroke the helical edge "B" of the annular groove has uncovered the right hand port, which enables the enclosed fuel to escape back through this port to the common suction manifold.

The position of the plunger stroke at which the helical edge "B" will uncover this port is adjusted by rotating the plunger through an axial angle by moving the control rod. This is normally done by the governor.

Moving the control rod in towards the engine, the output of the pump is reduced to nothing, as in "5". Moving it in the other direction, i.e., towards the observer, or out from the engine, increases the output as in "2" and "3", until the maximum is reached as at "1".

When the helical edge "B", uncovers the port in the plunger barrel near the end of the delivery stroke, the pressure of the imprisoned fuel oil is immediately reduced so that the delivery valve returns to its seat at once, thus cutting off communication between the pump and nozzle until the next delivery stroke.

The delivery valve, Fig. 42-3, is an ordinary mitre faced valve with a guide which has a circular groove in it, dividing the valve into two parts. The lower part has four longitudinal grooves communicating with the circular groove. The upper part of the valve is a small piston which has a highly ground plunger fit for the valve seating. When the plunger is on its delivery stroke and the pressure of the fuel is raised, the delivery valve is also raised until the fuel

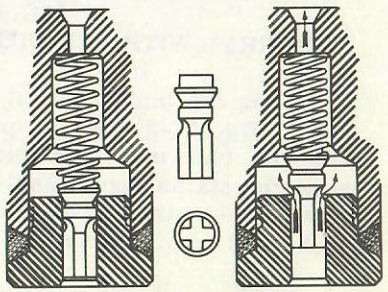


FIG. 42-3
DELIVERY VALVE

under pressure can escape through the longitudinal groove and over the valve face to the nozzle. As soon as the annular groove in the plunger uncovers the by-pass port and releases the pressure in the barrel, the delivery valve under the influence of its spring and the great difference in pressure between the plunger barrel and delivery pipe returns to its seat.

As the delivery valve seats, the small piston part of the valve sweeps down the valve guide with a plunger action increasing the space in the delivery pipe by a measured volume and this has the effect of greatly reducing the pressure in the pipe. The fuel pressure being thus reduced from its maximum of approximately 7000 psi to a much lower pressure, the valve is allowed to snap to its seat immediately, terminating the spray of fuel into the cylinder without any dribbling.

Fuel Injection Pump Delivery Valve Removal

If it becomes necessary to remove a delivery valve first disconnect the fuel injection pipe from the pump and then remove the delivery valve holding nut on the top of the pump. To loosen this nut use a pipe on end of wrench and give a strong steady pull. DO NOT LOOSEN OR TIGHTEN THIS NUT BY USING A HAMMER. When the nut is loose, remove the nut and delivery valve spring. A special tool is provided for the purpose of pulling the delivery valve. This tool works on the same principle as a gear puller. However, it is best to replace the assembly. Never install a new valve in an old seat or vice versa. This valve can be reground taking extreme care not to let any grinding compound get on the guide or small piston part of valve. The pump delivery valve is equipped with a solid copper gasket between the valve and the delivery valve holder. Either anneal the old gasket or apply a new one before reassembling.

Dismantling Fuel Injection Pump

If it becomes necessary to dismantle a pump, Fig. 43-3, first obtain a pail of clean filtered fuel oil in which to rinse the parts. Make sure the vise and other tools are clean. Cover the bench with a large sheet of clean paper. Fasten the pump in a vise with its bottom flange up, holding the pump by the delivery valve holding nut. Do not hold it by the body.

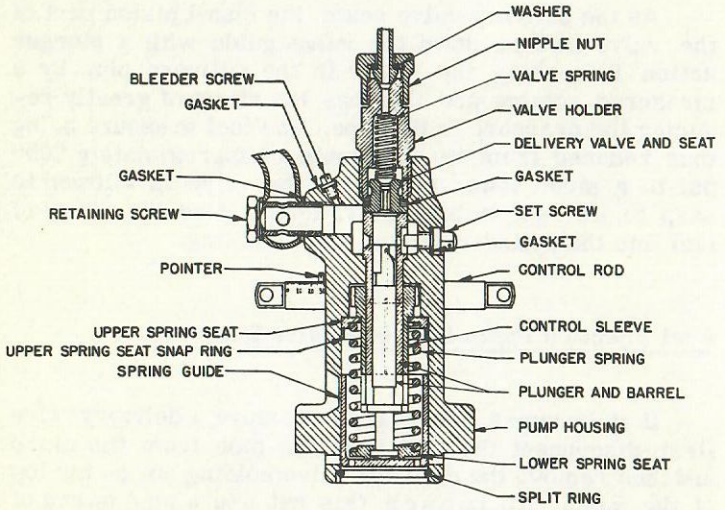


FIG. 43-3
FUEL INJECTION PUMP

Press down on the spring guide and insert a piece of drill rod in the hole provided for this purpose on the side of the pump housing fit. This will hold the spring guide down and with the aid of two screw drivers, remove the split ring. Press down on the spring guide, pull out the drill rod and remove the spring guide, spring seat, spring, plunger and control sleeve. When these are out remove the control rod set screw and then the control rod.

Turn the pump over and fasten it in a vise. Holding it by the flange, unscrew the delivery valve holding nut.

With the aid of the delivery valve pulling tool, previously described, remove the delivery valve from the housing. To remove the plunger barrel, remove set screw and push the plunger out through the top.

Do not at any time remove the point, pointer fastening screw, or adjusting washer, as these are set and should not be touched, otherwise it will be impossible to get the same output from each pump. The control rods are set with shims added behind the pointer to give an equal amount of fuel to each cylinder. When installing a new pump, adjust governor linkage where the control rod connects to the clevis so that the pointer on the new pump indicates the same as the original pump in all positions. For instance, if in "stop" position, the pointer on the pump is at 7 millimeters, set the new pump so that the pointer is at 7 millimeters. If, after setting the pump in this manner, there is a fuel knock, reset rack by turning the clevis 1/2 turn, clockwise. There should never be more than one-half millimeter variation between the pumps.

Reassembling Fuel Injection Pump

Thoroughly wash and rinse all the parts before assembling, never wipe them with a cloth or piece of waste. Rinse off each piece and then assemble it wet in the pump body. Make sure that the seat between the plunger barrel and body is clean; carefully scrape off any signs of dirt as this joint must be tight to insure against leakage down into the spring chamber. The plunger barrel must be located so that the long slot is towards the locking pin. Screw the locking pin up tight and make sure that the plunger barrel moves up and down freely. Install the delivery valve and seat with gasket in place; push the delivery valve down with the fingers as far as possible and then screw down in place with nut. Never screw the valve in place with a wrench. The valve should seat by hand, but if it does not, remove the valve and start over again. After the valve is on its seat use a wrench to tighten up the nut, but do not strike with hammer. Use a pipe to get a steady, even pull.

When all parts are tight, remove from the vise and turn the pump over and fasten in the vise again holding the pump by the delivery valve holding nut. If the control rack has been removed install the control rack so that the tooth that is notched on the rack is up and visible through the slot cut in the pump body for this purpose. Then, put in the stop screw for the control rod. Next, install the control sleeve, making sure the slot on the sleeve is directly in line with the slot on the control rod. When the slots are in line, lower the upper spring seat in place and install the snap ring. Install the spring. Assemble plunger in the plunger barrel making sure that the slot on the turning wings of the plunger line up with the slot on the control sleeve.

Put the lower spring plate over the end of the plunger and lower in place. Install spring guide and press down to make sure turning wings on plunger mesh with long slot on regulating sleeve. If everything is assembled properly, press down on the guide and hold it down with the aid of the drill rod through the hole and apply split ring.

IMPORTANT: Before removing the drill rod, remove barrel set screw and put the control rod in the "stop" position and note opening through the hole. This should never be more than a half hole or less than one-third hole. If this is not the case, dismantle the pump and check assembly.

On the older style pumps, the assembling marks are a little different. When assembling one of these, the two center punch marks are to be up and just so they are visible on both sides of the pump body. On the flange fit of plunger body will be found a center mark. At the bottom of large slots in regulating sleeve there is a center mark. This mark is to be meshed with the control rod so that it is directly in line with the center mark on the body flange. The plunger also has a center mark on the turning wings; this is to be in line with the other center marks. The rest of the assembly is the same as has been described.

Fuel Injection Pump Timing

To check the timing of all fuel pumps, bar the engine over in the direction of rotation, or counterclockwise when viewed from the generator end, until the timing mark on any one fuel pump spring guide is beginning to rise. Continue to bar the engine over until the pointer in the end cover is adjacent to the mark on the barring wheel. The piston of this cylinder is approaching Top Dead Center on its compression stroke and is at the correct crankshaft angle of 15 degrees B.T.C. With this crankshaft setting, the mark on the fuel pump spring guide should be line-in-line with the two stationary marks on the pump window, Fig. 44-3.

If these marks do not line up, remove the cover plate on front of the pump drive casing, but first turn all the cutout pins to their inoperative position by disengaging them from the cutout shaft and turning them to the right about 180 degrees or one-half turn.

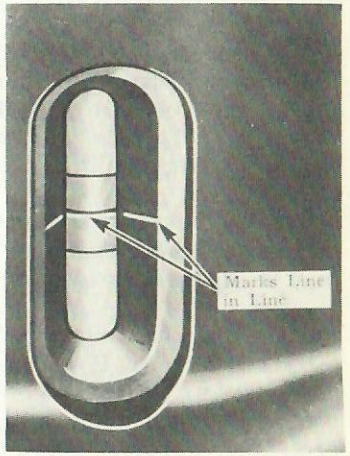


FIG. 44-3
PUMP TIMING

Move the manual trip lever on the end of the pump casing until the trigger released the cutout shaft, thus allowing it to move to the left or cutout position. If the above instructions are not followed, and the cutout cover is removed, this shaft and all cutout pins will drop into the cutout position as soon as the cover is moved out far enough to allow the trigger to become disengaged from the end of the shaft.

After the cutout cover has been removed, loosen the tappet cap nut until free; then turn the tappet adjusting screw up or down, whichever is required, until the timing

marks are line-in-line. Tighten the tappet cap nut. The pump will then be properly timed.

Continue on through the firing order 1-3-5-6-4-2 to check the timing of the remaining pumps, i.e. if No. 6 pump is the first one checked, the next will be No. 4, then No. 2, No. 1, No. 3 and No. 5.

After reassembling the cover, reset the trip shaft and turn all the cutout pins to their operating position. It is always best, after this cover has been removed and reassembled, to start the engine and trip the overspeed cutout by the manual lever to be sure that all the cutout pins function properly.

When checking the pump timing, if the mark on the barring wheel has been turned beyond the pointer, do not move back to it, but go back beyond it and again come up to pointer. This is very important as all backlash must be out of the gears in order to get a true reading.

If there is any question about the fuel pump timing marks on the barring wheel not being correct, the timing may be checked as follows:

With a protractor, check the number of degrees the locomotive is out from true level. This must be taken crosswise of the locomotive and should be taken on some machined surface of the engine. Then, with the protractor set to 15 degrees, add to it (or subtract from it) the number of degrees the locomotive is out of level. Place the protractor on the crank web and turn the crank very slowly in the proper direction until the bubble in the protractor is centered. The pump at this cylinder should be line-in-line.

To check for the proper setting of the protractor, the following example is given. If the locomotive is setting so that it is five degrees low on the fuel pump side and the engine timing is 15 degrees B.T.C., set the protractor to 10 degrees B.T.C. If the locomotive is 5

degrees high on the fuel pump side, set the protractor to 20 degrees B.T.C.

The fuel pump rack stops on the 660 HP engine are set at 24 MM and on the 1000 HP engines at 22-1/2 MM. Individual rack adjustments may be made where the rack connects to the vertical lever in back of the pumps. Remove the pin and turn the turn-buckle in or out (1/2 turn equals 1/2 MM adjustment on the rack).

Fuel Injection Pump Identification

Engine H.P.	Rack Setting: Stop Position	Rack Setting: Full Load Position	Bosch Designation: New APF1D	Bosch Designation: Re-conditioned APF1D
600 or 660	9.5-10 mm	24 mm	160-T-82	160-PS-82U
1000	7 - 8 mm	22.5 mm	200-T-82	200-PS-82U
900	6 - 7 mm	21 mm	200-T-82	200-PS-82U

It should be noted that the only way to determine the difference between 660 HP and 1000 HP Pumps is by the Bosch pump designation number. The number starts with 160 for 600 and 660 HP Pumps and 200 for 900 and 1000 HP Pumps.

FUEL INJECTION NOZZLE

The fuel injection nozzles, Fig. 45-3, are located in the cylinder heads and their function is to admit the fuel into the combustion space in a finely atomized condition and distribute the spray so that each particle of fuel will come in contact with sufficient oxygen for complete combustion.

The nozzle is a vital part of the engine and must be kept in perfect condition if the engine is to operate smoothly and economically. If, however, excessive leakage is noted from the drop line or the needle valve is stuck, or the nozzle holes are plugged, it is advisable to replace the complete unit and have the defective one reconditioned.

Be sure all fuel injection tubes are lined up exactly with nozzle inlets and injection pump outlets before nipple nuts are tightened. After tightening, apply all pipe clamps.

Be absolutely certain that the correct size of injection tubing is used when replacements are made. The correct size and horse power is stamped on the fuel pump nut of each injection tube.

Oil is fed to the nozzle from the fuel injection pump and tubing, through the fuel inlet stud and down a drilled passage in the nozzle holder body which connects with a machined groove on the top of the nozzle. From the groove to the underside of the nozzle valve are drilled three holes equally spaced.

As the fuel pressure from the pump builds up, the valve in the nozzle is raised from its seat and injection of fuel begins. When the fuel pressure, timed from the cam under the pump, drops below the pressure at which the spring has been set, the valve returns to its seat.

The valve has a very fine fit in the nozzle body and any leakage finds its way into the nozzle holder and is drained away through a pipe from the leak-off stud to a manifold where the drips from all the nozzles in the engine are collected and led back to the main fuel tank to be used over again. A small amount of leakage by the valve is a means of lubricating the valve in its fit in the nozzle but as seen at the inspection window in the drip collecting manifold, it should not be more than a couple of drops a minute.

If a steady stream of fuel is found, the nozzle should be removed and tested. The ground joint between the nozzle and nozzle holder should be examined for particles of dirt or score marks. If the leakage cannot be remedied or cannot be located, the nozzle should be returned to the manufacturer for reconditioning.

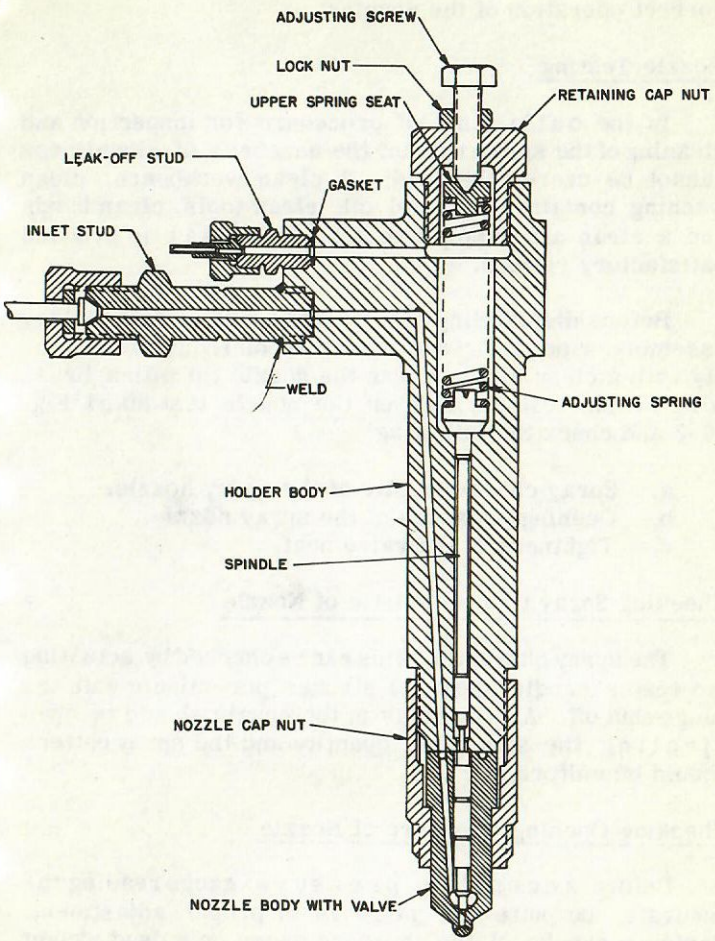


FIG. 45-3
FUEL INJECTION NOZZLE

Under no circumstance must any drain line be plugged. The drains must be open to the atmosphere for correct operation of the nozzles.

Nozzle Testing

In the outlining of procedure for inspection and cleaning of the spray nozzle, the necessity of cleanliness cannot be overemphasized. A clean workbench, clean washing containers of fuel oil, clean tools, clean hands and a clean air supply are all essential to produce satisfactory results.

Before dismantling the nozzle and nozzle holder assembly, wipe all dirt and loose carbon from the assembly with a clean cloth. Clean the nozzle tip with a brass wire brush, test the unit on the nozzle test stand, Fig. 46-3 and check the following:

a. Spray characteristic of the spray nozzle.
b. Opening pressure of the spray nozzle.
c. Tightness of the valve seat.

Checking Spray Characteristic of Nozzle

The spray characteristics can be checked by actuating the tester handle about 20 strokes per minute with the gauge shut off. All the holes in the nozzle should be open ejecting the same fuel quantity and the spray pattern should be uniform.

Checking Opening Pressure of Nozzle

Before accepting pressure gauge readings as accurate, be sure the gauge is in proper adjustment. Periodic checks of the pressure gauge on a dead weight tester are absolutely necessary. The pressure gauge may be damaged when the nozzle test stand pump handle is moved rapidly. Therefore, the gauge shutoff valve should always be kept closed except when actually checking the opening pressure.

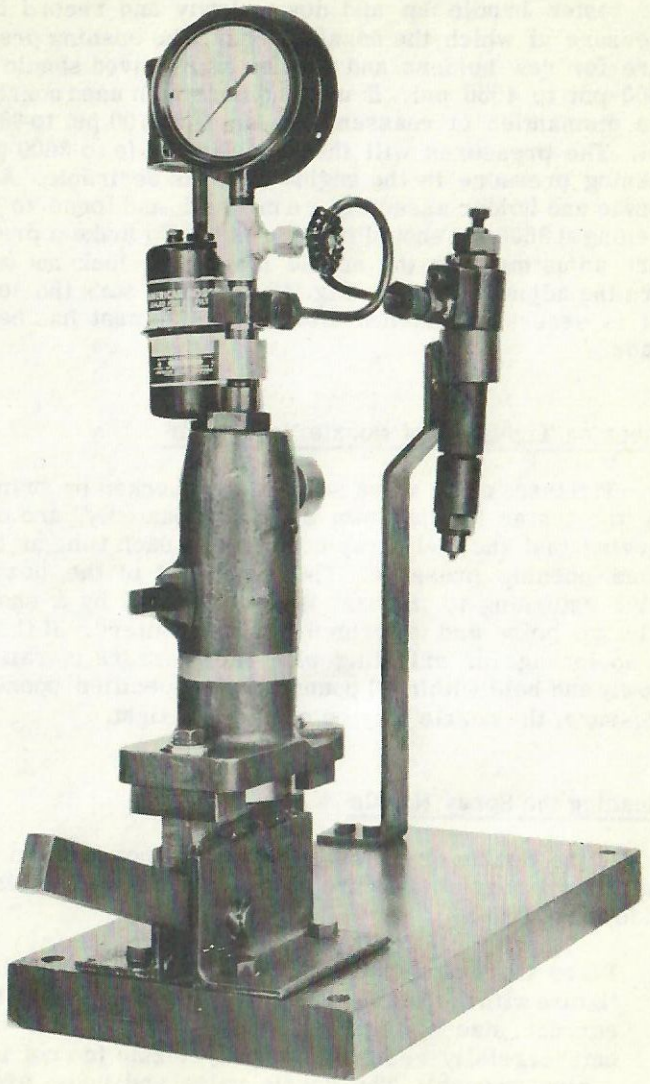


FIG. 46-3
NOZZLE TEST STAND

To check the opening pressure of the nozzle, move the tester handle up and down slowly and record the pressure at which the nozzle opens. The opening pressure for new holders and nozzles as received should be 3900 psi to 4050 psi. If used holders with used nozzles are dismantled or reassembled, set for 3700 psi to 3800 psi. The pressures will then usually settle to 3600 psi opening pressure in the engine which is desirable. Any nozzle and holder assembly removed and found to be opening at 3600 psi should not be reset. To make a pressure adjustment on the nozzle loosen the lock nut and turn the adjusting screw, Fig. 45-3. Make sure the lock nut is securely tightened after an adjustment has been made.

Checking Tightness of Nozzle Valve Seat

Tightness of the valve seat can be checked by bringing the tester handle down slowly, repeatedly, and observing that the fuel spray commences each time at the same opening pressure. The movement of the nozzle valve returning to its seat is accompanied by a sharp staccato noise and is termed "nozzle chatter". If there is no leakage or dribbling when the pressure is raised slowly and held within 50 pounds of the specified opening pressure, the nozzle may be considered tight.

Cleaning the Spray Nozzle

If the nozzle or the spray pattern is not uniform or one or more nozzle holes are plugged, service the nozzle as follows:

1. Place the nozzle holder assembly in the holding fixture with the nozzle pointing upward and using the correct size box wrench, unscrew the nozzle cap nut; carefully remove the spray nozzle (do not use a pipe wrench). The nozzle valve and body are a mated assembly and cannot be interchanged with

lapped parts from other spray nozzles. Protect the lapped surface at the end of the nozzle holder by screwing the nozzle cap nut back in place.

If nozzle is stuck in nozzle holder cap nut because of carbon formation, carefully remove by using a brass rod, one end of which conforms with the contour of the nozzle tip.

2. Soak the spray nozzle in clean fuel oil and withdraw the nozzle valve from the nozzle body. Examine for gum, carbon deposits at or near the valve seat. If deposits are present, the nozzle body and valve should be allowed to soak thoroughly in a suitable mineral spirit washing solution. If large deposits of hard carbon are present on the nozzle valve and inside and outside of the nozzle body; soak the units in cleaning solvent; Bendix "Metal-Clene", Karbonoff Cleaner, "Gunk", Magnus 755, Turco Transpo or Acetone. Cleaning may require from a few minutes to several hours depending on the cleaner used and the condition of the nozzle and valve.

3. Nozzle valves which are stuck due to scale or other abrasives lodged between nozzle valve and body and which cannot be removed after thoroughly soaking in the solvent should be removed in the nozzle valve ejector.

4. Do not use a cleaning needle on a plugged nozzle hole until after the nozzle body has been soaked several hours or longer in solvent. This loosens the carbon and generally the holes can be cleaned by using an air hose at the nozzle valve hole. If this is not successful, they should be cleaned by probing with a cleaning needle held in a pin vise. It is important that the cleaning needle be a size smaller than the spray hole. The operator must be careful in cleaning these holes to prevent the needle from being broken off in the hole as it is difficult and sometimes impossible to remove broken pieces.

5. After soaking in the cleaning solvent, the nozzle body and valve should be thoroughly rinsed in clean fuel oil several times. Before fitting the nozzle valve to the nozzle body, dip these parts in clean fuel oil. With the aid of fuel oil as a lubricant, the nozzle valve should slide slowly into place without any binding action when the nozzle is held at a 45 degree angle. If binding is present, the condition may usually be rectified by applying a little mutton tallow or a paste of talcum powder mixed with a few drops of clean fuel oil on the nozzle valve shank and working the valve back and forth in a rotating manner. Do not strike the valve seat when working the valve in the body. Thoroughly rinse both valve and the nozzle body after each operation.

   Do not use hard or sharp tools, emery cloth or crocus cloth. The nozzle valve can be cleaned with mutton tallow used on a cloth or felt pad. The valve may be held by its stem in a revolving chuck during this operation. A brass wire brush will be helpful in removing carbon from the valve.

   A special nozzle body pressure chamber scraper and nozzle valve seat scraper, should be used to clean the nozzle body internally.

Examination of Parts

Examination should be attempted until all parts have been carefully washed and all grease and dirt removed.

Examine all parts carefully. In general, it will be found that there has been only minute wear but abnormal conditions, such as moisture or corrosive fuels may have caused damage to the extent that parts will require replacement.

Holder Body

The lapped surfaces at end of the nozzle holder must be free from scratches which cause imperfect seals between these surfaces and the upper lapped surface of the nozzle body. It is possible to remove small scratches on the lapped ends of the holder and nozzle body by lapping them with the aid of a lapping plate and lapping compounds. The nozzle holder should be held in the nozzle holder fixture for this operation.

Charge the lapping plate with American Bosch fine compound BM 10007 or equivalent and move it across the surface of the nozzle holder until the scratches are removed. During this operation care should be exercised to keep the plate square with the nozzle holder to insure contact with the entire area being resurfaced. The plate must be moved steadily with no rocking motion.

Remove all traces of lapping compound with cleaning fluid or fuel oil and thoroughly blow off with filtered compressed air.

All threads in holder must be in good condition.

Nozzle Cap Nut

Remove all carbon deposits on both inner and outer surfaces. Inspect it for cracks due to overtightening or a damaged lower seating surface. The seating surface which contacts the copper gasket may be restored by rubbing it on emery cloth. Any cap nut which cannot be reconditioned must be replaced with a new one.

Pressure Adjusting Spring

If the spring is scratched or pitted it must be replaced with a new one. Always replace questionable springs.

Reassembly of Nozzle Holder and Spray Nozzle

The nozzle holder is assembled first by placing the nozzle holder fixture. Assemble spring spindle, spring and upper spring seat in nozzle holder and then apply retaining cap nut. Apply lock nut to adjusting screw and apply to cap nut turning it down until it strikes upper spring seat. Remove nozzle holder from fixture and replace in inverted position. Place nozzle on the nozzle holder in inverted position and lower cap nut over nozzle. Put centering sleeve over nozzle and hand tighten nozzle cap nut. Remove centering sleeve and finish tightening to a torque of 290-310 foot pounds.

Nozzle must now be tested and pressure set by turning adjusting screw down to increase pressure and up to lower pressure making sure lock nut is securely tightened when correct pressure is obtained.

Nozzle Holder and Tubes

One of the worst possible engine failures can be caused by fuel leaking into the crankcase and CAUTION must be used in correctly tightening the following and inspecting and checking the fuel leakage.

The nozzle cap nut, if not tight, will cause large amounts of fuel to leak upward onto the cylinder head where it will mix with lube oil and drain back into the crankcase. The retaining cap nut must also be tight or fuel will seep out on to cylinder head and drain back to crankcase. The fuel leak-off stud must be tight and also the nuts holding the injection and overflow tubes to the holder. Care must also be taken to see that these two nuts do not jam against the nipples when tightening the respective pipes; if they do, the nuts must be ground off.

There is only one gasket in the entire holder assembly, and this is under the leak-off connection. This connection should be tried for tightness before connecting the drain pipe.

When installing fuel tubes, care must be taken not to spring the tube to catch the nut. If the fuel tubes do not line up with their connections, they must be bent to fit. The fuel tubes must also be securely clamped to prevent any vibration or chafing.

Removing the nozzles for testing and checking once a year has proven very satisfactory on switching locomotives. When a nozzle valve sticks in the nozzle, this can be dectected by smoky exhaust and engine pounding. The defective nozzle can be located by cutting out cylinders in rotation and when the nozzle is isolated, it should be changed as soon as possible.

Fuel Injection Nozzle Gasket

A gasket .040" thick is used between the injection nozzle holder and the cylinder head. This gasket varies in thickness on different makes of engines and it is very important that only the gasket recommended by this company be used. If this gasket is too thick, the injection nozzle is raised and the spray will strike the cylinder head interfering with proper fuel injection, causing poor combustion.

When removing an injection nozzle holder for inspection or for replacement, the gasket should also be removed for inspection and as a guard against inserting a second gasket on top of the original, which in effect would be the same as using a thick gasket.

Fuel Injection Nozzle Identification

Name of Part	Identification No.	Engine HP
Nozzle	DL-140-U-271	600 and 660
Nozzle	DL-155-U-390 (Bosch) A-155-9-.35 (Alco)	1000
Holder	AKB-200-U-54	600, 660, 900, 1000

All nozzle numbers ending in 271 are for 600 and 660 HP engines. All nozzle numbers ending in 390 or .35 are for 1000 HP engines. These numbers are found on the nozzle body.

FUEL OIL SPECIFICATIONS

A.S.T.M. 2-D except a minimum flash point of 120° F.

ENGINE BALANCING
COUNTER WEIGHT LOCATION ON GENERATOR FAN

When applying a new generator fan, generator, or reinstalling a generator, care should be taken to be sure the weight mounted on the generator fan is located in the proper position, otherwise excessive vibration will occur.

The original generator fans now in service on many locomotives were made of aluminum in four sections, one of which has a counterweight attached. On switchers and road switchers only, a welded steel section having counterweight attached was substituted for one of the four.

Still later a solid one piece steel all welded fan was substituted in a few cases for the aluminum fans with or without the one steel quarter section.

It is necessary to remove the generator from the engine in order to remove this one piece fan. The counterweights on the one piece fans are located in slightly different places than on the four section fans.

The following are the locations for the counterweight on these different type fans:

660 HP Switching Locomotive

Old Style Fan with Steel Quarter Section

Place cranks Nos. 1 and 6 about 20° B.T.C.

Steel fan section now at top center.

Counterweight also on top center on radial center line passing through center fan holding bolt boss.

New Style Solid Fan

Place cranks Nos. 1 and 6 15° B.T.C.

Apply fan to generator armature spider with counterweight in line with same cranks, Nos. 1 and 6.

Fan holding bolt boss will be on top center. This boss corresponds with boss in center of former steel quarter section.

1000 HP Switching Locomotive

Old Style Fan with Steel Quarter Section

Place cranks Nos. 1 and 6 about 20° B.T.C.

Steel fan section now at top center.

Counterweight is now 10° ahead of radial center line of this fan quarter section.

New Style Solid Fan

Place cranks Nos. 1 and 6 15° B.T.C.

Apply fan to generator armature spider with center line of counterweight 6° A.T.C.

Fan holding bolt boss is now directly on top center. This boss corresponds with boss in center of former steel quarter section.

1000 HP Road Switching Locomotive

Should a one piece fan ever have to be applied to a road switcher in the field, the instructions for 1000 HP switching locomotive given above should be followed. Then, when the fan has been applied the counterweight weighing 8.34 pounds and bolted to the fan should be removed.

MAIN BASE

The main base has main bearing seats and caps which are accurately bored in line to receive the main bearing shells. Openings on each side give access to the shaft and its bearings. The opening on the forward end is completely enclosed by the main base end cover assembly while the oil catcher casing seals the drive end. The flanges of this casing are sealed with a non-hardening compound which may be removed with alcohol. A lip turned concentric with the main bearing bore is provided on the drive end as an aid in aligning the generator frame. Space is provided on the drive end for the gear train.

MAIN FRAME

The main frame has provision for the installation of the cylinder liners. It is secured to the main base by studs anchored in the frame. Eight studs are fitted in the upper side at each cylinder for the attachment of the cylinder heads.

Water flow to the cylinder heads is through grommet-sealed water passages communicating between the cored water spaces of the head and frame.

A cast-in header between the water pump suction head and a flange boss on the front end of the frame provides passage for the circulating water from the cooling radiator discharge line to the water pump. Two 3/16 inch holes drilled in the inner wall of this head serve as vents and drains.

When testing the frame and liner assembly hydrostatically, make sure that the suction header is filled to capacity. The inlet and exhaust valve push rods, with attendant gear such as cam rollers and their brackets, and the main camshaft are also housed in the main frame.

Liner Seat Width	.572 - .575
Top Bore for Liner	14.791 - 14.796
Bottom Bore for Liner	14.063 - 14.065
Fit Bore for Liner	14.219 - 14.221
Bore for Camshaft	5.005 - 4.995
Out of Round Bore for Liner (Limit)	.005

VALVE LEVER MECHANISM

The air inlet and exhaust valves are operated from the main camshaft by means of the lifter, pushrod and rocker shaft (valve lever) assemblies.

Each cylinder unit has a lifter assembly which consists of two pushrod lifters having a common shaft as a fulcrum and a supporting bracket which is secured to the main frame by four ream bolts. The lifters have rollers which are forced to follow the profiles of the cams by the heavy valve springs. The air inlet valve rocker shaft has a buffer spring which supplements the action of the springs on the valve itself.

The pushrod ends of the lifters are fitted with hardened steel seats into which the lower ends of the pushrods are fitted. The pushrod ends of the rocker shafts carry hardened steel adjusting screws which, having a spherical head, ride in hardened seats fixed in the upper ends of the pushrods. These screws are for the purpose of adjusting the valve clearances. The valve ends of the rocker shafts are fitted with valve tappet assemblies which may be used for adjusting the clearance of individual valves. These tappets have "gliding pieces" which, held in assembly by steel snap rings, serve as bearing surfaces.

Valve Lever Lubrication

Lubricating oil is supplied to the mechanism of each cylinder unit from the main oil header through a copper tube which is connected to the lifter bracket. Machined passages in the parts lead oil to the several bearing surfaces of the lifter assembly. Holes drilled in the pushrod seats in the lifters and in the balls on the lower ends of the pushrod permit oil to flow into the rods through which it is passed to holes in the ball seats at the upper ends. Drilled passages and an annular groove machined in each adjusting screw, communicating with additional passages in the respective rocker shafts, convey oil to an annular space between the fulcrum shaft bushings. From this

space the oil flows through the clearance between the bushings and the fulcrum shaft to radially drilled holes in the bushing which lead to circumferential grooves in the outer surface of the bushings. From these grooves oil passes to a metering plug on top of the exhaust valve rocker arm which controls the amount of oil permitted to splash over the valve tappet arrangement.

Part of the oil splashed is caught by the cup of the tappet screw from which it flows downward lubricating the ball seat. A hole drilled in the gliding piece furnishes passage to the bearing surface.

Rocker Box Removal

Remove the four cotter-pinned nuts that hold each of these assemblies to their respective cylinder heads and lift the assemblies from the engine with suitable tackle.

Valve Lever Maintenance

1. Remove the two Allen head pipe plugs which are located in the after side of each casing.

2. Remove the two clamping bolts of the exhaust valve lever fulcrum pin and by tapping a rod inserted through the upper pipe plug hole, drive the fulcrum pin from the casing and remove the lever assembly.

3. Remove the two clamping bolts of the air inlet valve lever fulcrum pin and by means of a rod inserted through the lower pipe plug hole, also drive this fulcrum pin from the casing.

4. Thoroughly clean the lever assemblies by immersing them in Diesel oil or kerosene and then blow the oil passage clear by air pressure.

5. Examine the fit of the respective fulcrum pins

with their bushings. If the clearance is found to be excessive, check the diameters of the parts concerned with the dimensions shown in the table of clearance and renew the part or parts at fault.

6. Examine the valve tappet parts for wear and cracks. Renew those of doubtful appearance.

7. Examine the ball of the adjusting screw on the pushrod end of the respective levers. If scored, or otherwise damaged, replace the adjusting screw. Do not attempt to reface the ball.

Push Rod Maintenance

1. Check the rods for straightness.

2. Examine the ball seat on the upper end for scoring, etc. Likewise examine the ball on the lower end. These parts are hardened and if properly lubricated during operation, should show no wear. However, if one is found to be faulty in appearance, install new rod assembly.

CYLINDER HEADS

The cylinder heads have cored spaces for cooling water. Water passages to the cylinder block are fitted with synthetic rubber grommets. Cooling water discharge from the heads is carried to the water outlet header by individual elbow connections. Cored passages also permit the admission of scavenging air and the expulsion of exhaust gases. Metal to metal joints of the male and female type between the cylinder heads and cylinder liners, prevent the escape of gases from the cylinders.

Each head has suitable chambers for two air inlet valves, two exhaust valves, and a fuel injection nozzle.

Seats are machined in the heads for the exhaust and inlet valves. Bosses are provided for the adaptation of the compression relief plugs from which cast-in steel tubes furnish communication with the combustion spaces.

Uniformly spaced holes are provided for the cylinder head holding-down studs.

Secured to the top of each unit is a casing which, with a suitable cover, encloses all gear mounted on the head.

Air Inlet Valves

Each cylinder head has two air inlet valves which are opened simultaneously by means of a cam on the main camshaft, which act through the pushrod and valve lever assemblies. Rapid closing of each valve is accomplished by means of two steel springs in the individual valve assemblies. These valves which reciprocate in cast iron guides, are made of steel. A hardened steel cap serves as a bearing surface for the valve tappet gliding piece and prevents wear on the comparatively soft valve stem. The split lock which holds the spring retainer in place is held in grooves in the valve stem by the tapered fit in the retainer. A fiber washer is applied over the split lock to prevent oil from running down the valve stem. The lock spring which is fitted in a groove in the spring retainer holds the retainer, split-lock and valve in assembly. The buffer spring keeps the inlet cam roller in contact with the cam and prevents clatter of the inlet valve operating mechanism and pounding of the roller against the cam.

Exhaust Valves

The exhaust valves are assembled and operated in pairs in a manner similar to the air inlet valves. However, in material and construction, the valve proper differs considerably from the inlet valve. The valve head section and the stem are made of two different

steels which are welded together about four inches above the valve head. The stem section is made of a comparatively hard high grade steel while the head section is made of a softer steel which will not crack when subjected to the rapid changes in temperature experiences in service. In addition, the stems are several inches longer than those of the inlet valves to suit the position of the exhaust rocker levers. The use of a buffer spring on the exhaust valve gear is not necessary.

Cylinder Head Removal

1. Remove air and exhaust manifold cap screws from cylinder head.

2. Remove the cylinder head nuts on each unit.

3. Remove the cylinder heads in turn by means of the "cylinder head removing bar" and suitable tackle.

4. As each head is removed, place it on a wooden platform with the combustion space side down.

5. Remove the air and exhaust valves in accordance with the following:

   Remove all valve stem caps.

   Remove all lock springs from the spring retainers by prying with a screw driver or other similar tool inserted in the recess provided in the spring retainers. Screw the fulcrum block of the valve spring compressing tool on the valve lever casing stud nearest the valve concerned. Place the tool sleeve hand on the valve spring retainer and hook the compressing lever under the pin of the fulcrum block. Compress the valve spring until the gasket and split lock can be removed. After removing these parts, remove the valve spring retainer and valve spring.

6. Repeat the above operations on the other air and exhaust valve assemblies.

7. Turn the head on its side and remove the valves.

Cylinder Head Tightening

Particular care must be used in tightening the nuts of the cylinder head studs. Excessive tightening may cause distortion of the cylinder head, liner and cracking of the block at the liner seat.

When there is a leak at the gas joint between cylinder head and liner or at the water joint between cylinder head and block and the stud nuts have been tightened to normal tightness, no attempt to stop the leak by further tightening should be made. The cylinder head should be removed and all parts carefully checked to determine the cause.

Water Leaks

Causes

1. Defective gasket.
2. Gasket improperly placed.
3. Surface for gasket not clean.
4. Surface for gasket pitted.
5. Cylinder head water jacket cracked.
6. Leak at joint, cylinder liner to frame.
7. Leak around cylinder head studs or in frame above the liner seat.
8. Cylinder head not tightened down evenly.

Corrections

1., 2., and
3. Require inspection and care in assembling parts.

4. Clean the surface and apply a sealing compound filling the pits.

5. Water test cylinder head at 50 pounds gauge pressure.

6. To check for leak at this position remove cylinder head. Tap the six vent holes between the cylinder head studs for 1/4 pipe plug. The two water passage holes can be sealed by rubber gasket held in place by a bar of iron which can be secured by placing a piece of pipe around the studs each side of water passage then use the cylinder head stud nuts to secure the pipe. The liner is held in position with a bar secured with the cylinder head stud nuts.

   Water test at 50 pounds gauge pressure. If a leak is present, inspect the liner seat in the frame also the seat on the liner for evidence of location of the leak. If liner seat leaks, install liner and apply gasket on top of block to seal the joint between liner and block. This gasket is held in place when the head is applied. To check the liner seat in the frame for being true, a fixture will be required. The fixture is coated with prussian blue, then placed on the liner seat in the frame and rotated. The high points, if present will be marked with the prussian blue and the low points will show no marking. The high points are removed by scraping and a true bearing should be obtained. When scraping the liner seat in the frame, care must be exercised to keep the seat parallel with the top of the frame.

   To check the seat on the liner for being true, a fixture will be required. The fixture is coated with prussian blue, then placed on the liner seat and rotated. The high points will be coated with prussian blue and the low points will show no marking. The high points are removed by scraping and a true bearing should be obtained.

   When scraping the liner seat, care must be exercised to keep the seat parallel with the top of the liner.

7. A leak around the cylinder head studs can be checked by removing the cylinder head and water testing as outlined in (6). Leaks at this point can usually be corrected by removing the stud, cleaning the threads on the stud and in the stud hole. Then make up a thin paste using glycerine and litharge. Coat the threads on the stud, also the threads in the stud hole. Drive the stud and then let the paste set for as long a period as practical up to eight hours. Then the water pressure may be applied.

8. When installing a cylinder head, clean the seat in the liner and the seat on the cylinder head. Clean the gasket seating surfaces of the cylinder head and frame. Place the gaskets for the water joint in position. When the cylinder head is placed in position, care must be taken that the male fit on the cylinder head has entered the female fit in the liner. If any difficulty is encountered in getting the cylinder head down and the cylinder head has contacted the gasket, it is advisable to raise the cylinder head and determine if the gaskets are in the correct position and then lower the cylinder head to position.

   Before tightening the stud nuts check the pads on the cylinder head and the flanges on the air and exhaust manifolds to see that they are parallel.

   All nuts should be tightened hand tight, then opposite nuts should be tightened snugging up each nut the same amount. Then, with feelers or thickness gauge, check the clearance between the cylinder head and cylinder block at six points to determine if the cylinder head is being drawn down evenly. The clearance between the cylinder head and cylinder block is 1/16". At any of the

six points this measurement should not differ by more than .005 to .010 inch; tighten all nuts. Use a wrench four feet long with not over 200 pounds pull on it, which is the average pull of one man. Excessive tightening of the nuts might crack the head or cylinder block liner seat.

Gas Leaks at Joint Between Head and Liner

Causes

1. Seat on cylinder head or in liner not clean.
2. Seat on cylinder head or in liner burred or nicked.
3. Seat on cylinder head distorted.
4. Seat in liner distorted.
5. Cylinder head not tightened down evenly.

Corrections

1. and
2. Requires care in handling parts when disassembling and assembling and proper cleaning before assembling.

3. Distortion of the seat on the cylinder head can usually be attributed to excessive or uneven tightening of cylinder head stud nuts. To check if the seat is distorted, a surface plate is required. The surface plate is coated with prussian blue and then placed on the seat and rotated. The high spots will be marked with the prussian blue. The high spots are removed by scraping or lapping and a true bearing should be obtained.

4. Distortion of the seat for cylinder head in the liner likewise can usually be attributed to the excessive tightening of cylinder head stud nuts. To check if the seat is distorted, a fixture is required. The fixture is coated with prussian blue and then placed on the seat in the liner and rotated. The high spots will be marked with

prussian blue. The high spots are removed by scraping and a true bearing should be obtained. When scraping the seat in the liner, care must be exercised to keep the seat parallel with the top of the liner.

Scraping the seats reduces the clearance of piston to cylinder head and of cylinder head to block. When .025" to .030" has been removed from the seats, the entire lower surface of the cylinder head should be remachined to bring the height of the compression seal ring back to its original measurement of 1/4" which will give the correct clearance between piston to cylinder head and cylinder head to block.

Adjusting Air and Exhaust Valve Clearance

Bar the engine over until the timing mark on the fuel pump spring guide cup lines up with the mark on the fuel pump window on the up stroke. The cylinder on which the valves are being set will then have both its push rods off the rise of the camshaft. Check the timing mark on the fuel pump with the pointer and timing mark on the flywheel which is exposed when the barring hole cover is removed. Next remove the rocker box cover and insert feelers between the valve stem cap and the valve stem gliding piece. The clearance should be .016 inches with the engine hot or cold. If the clearance is not correct, loosen the adjusting screw lock nut on the valve end of the rocker arm and turn the screw up or down as required. When checking the exhaust valve clearance be sure to hold down the pushrod end of the rocker arm so that a false feeler reading is not obtained.

CYLINDER LINER

Cylinder liners fit in the cylinder block with a metal to metal fit. Each liner has a collar on its upper end which is fitted to a counter bore in the cylinder block.

Three synthetic rubber seal rings in grooves near the lower end of each unit seal the fit between the liner and the cylinder block. The upper rims are grooved to receive the mating projections of the cylinder head in male and female, metal to metal joints which prevent the escape of gases from the cylinder.

Cylinder Liner Removal

Due to the fact that the liner fits are metal to metal, it is generally necessary to break the fit loose by jacking from the bottom. Place a piece of rail across the base door openings, set a jack on the rail and jack against the lower liner puller plate until the liner has become free in the lower fit. Then lift the liner out with the liner removal tool.

Cylinder Liner Installation

Before installing a liner, first clean off the roughness on the lower liner fit in the cylinder block to prevent possible tearing and rolling of the liner seal rings as they enter this fit and apply liquid soap. Apply liner seal rings; soap the rings and fit and drop the liner into the cylinder bore. As the liner seal rings enter the lower fit, pressure will have to be applied to force the liner down. To do this, either reverse the liner puller tool or pry the liner down using blocks and a pry bar.

Cylinder Liner Wear Limits

Cylinder liner wear is measured by taking a micrometer measurement of the liner bore in a plane perpendicular to the crankshaft and in a plane parallel to the crankshaft 1/4" below the upper end of the piston ring

travel. Carefully clean carbon deposits before taking micrometer readings. If any of the measurements exceed the limits below, the liner should be scrapped.

	Max.
1. Out of circularity with liner in engine frame	.005
2. Recommended maximum diameter wear at top piston ring travel	.080

Liners must be removed for re-honing when the bore reaches 12.545. Such re-honed liners may be continued in service until the bore reaches 12.580 when the liner must be scrapped.

3. If a new liner and piston are installed with close skirt clearance of .021 or less, the out of circularity with the liner should not be in excess of	.003

CONNECTING ROD

The connecting rod made of high grade drop forged steel is bored on the piston end to receive the bronze piston pin bushing which is installed with a press fit of from .0025 inches to .0045 inches. The crank bearing cap is secured to its respective connecting rod by four

steel bolts to form the crankpin bearings. These bearings are provided with flanged shell halves. On older engines installed between the lands of the bearing caps and connecting rods are steel shims which are positioned by dowels. These shims are hardened and accurately ground to very close tolerances. Anchored to the inner sides of the bearing shims on the end sections are short babbitt lugs, which, scraped to slightly more than the nominal running clearance, form seals which prevent the escape of lubricating oil from the bearing. These shims are omitted on later engines.

The crankpin bearing bore and the piston pin bushing bore are bored simultaneously in assembly thus insuring parallelism and perfect alignment.

A dowel fixed in the crank bearing cap prevents movement of the shell in the cap.

The bearing bolts have a clearance fit of from .0105 inches to .011 inches diametrically. At the original assembly they are stretched to an elongation of .008 inches and reference lines are then stamped on the nuts and the connecting rods. When reassembling after an inspection or overhaul, it is very important that the same strain be applied to the bolts. A micrometer or dial indicator may be used as a positive means of checking the elongation.

All bearing bolts and nuts are stamped with identification numbers and when installed they must be located in holes bearing identical numbers. The bolts are drilled and the nuts castellated to provide passage for the cotter pins.

Although the bearing shell halves are machined to identical measurements they are not interchangeable because their projections are hand fitted to a particular cap or connecting rod. Suitable markings have been provided for identification and locating purposes.

Connecting Rod Bearing Application

Should it become necessary to renew a pair of bearing shells it is recommended that new shells be installed in a spare rod, tightened to the scribe marks and, using a mandrel ground to the size of the crankpin journal, measure the clearance between the mandrel and bearing. If the proper running clearance is not indicated, it will be necessary to scrape and fit the bearing until the proper clearance is obtained. The bearings will then be ready for application in the engine with the minimum amount of work.

The distance between the shell flange bosses of the bearing cap is approximately .043 inches less than that between the bosses of the connecting rod shell flanges. This arrangement protects the bearing bolts from any strain which might be applied if the bearing cap was subjected to side thrust.

As the shell halves are identical in dimension the lower shell half has a total clearance of .053 inches between the shell flanges and the cap bosses while the upper shell has a total clearance of but .010 inches.

The number of the cylinder unit, to which the connecting rod assembly belongs, is stamped on the connecting rod and on the cap at the bearing joint, on the main camshaft side of the engine. All other numbers are provided for the purpose of locating the parts of an assembly group and are not to be confused with the cylinder unit identification numbers.

Connecting Rod Bearing and Bushing Lubrication

Oil is led from one of the adjacent main bearings through a tube wedged in the crankshaft to the crankpin bearing. A radially drilled hole in the upper shell half and a communicating rifle drilled passage in the connecting rod conduct oil from the crankpin to the piston pin bushing. These passages receive a generous supply

of oil from a groove machined in the bearing surface of the upper shell half which extends, circumferentially, about 45 degrees on each side of the radially drilled hole.

The piston pin bushing is provided with annular grooves which are machined in the longitudinal center of the inner and outer diameters. Four equally spaced holes, communicating between these grooves, provide passage of the oil from the outer groove to the inner one, from which the oil flows through the clearance space between the pin and bushing, thus lubricating the parts.

Radially drilled holes in the pin conduct oil to the annular reservoir between the inner wall of the pin and the piston pin cups that are rolled in the pin ends. This reservoir aids in the lubricating of the bushing and piston pin.

PISTON

The piston made of a hard close grained aluminum alloy, or cast iron, is strongly bossed to support the piston pins. They are of the trunk type with concave heads which are suitably recessed to provide clearance for the heads of the inlet and exhaust valves.

There are eight piston ring grooves. Six of these are located above and two below the pin bosses. The five uppermost grooves are fitted with compression rings while the groove immediately above the piston pin and those in the piston skirt are provided with lubrication oil wiper rings.

The piston with the caps installed is relieved for a considerable area about the piston pin bores.

The piston pin is fitted in their bosses with a diametrical clearance of approximately .0015 inches. When using an old pin in a new piston some scraping may be necessary to obtain this clearance.

For lifting purposes, two 5/8 inch tapped holes have been provided in the piston head.

Piston Pin

The piston pin, made of high grade drop forged steel is case hardened and accurately ground to size. In design, it is of the full floating type, being free to revolve and move, laterally within the limits of the piston pin caps. Cups, expanded into the ends of the pin, form an annular oil reservoir which insures an ample supply of oil being present for lubricating and pin cooling purposes. A number of radial holes of small diameter, communicating between this reservoir and the bearing surfaces, provide passage for the oil which is supplied from the crank pin through a rifle drilled passage in the vertical center of the connecting rod and annular grooves in the pin bushing.

Piston Pin Bushing Installation

The piston pin bushings furnished as spares may be installed as replacements in any of the rods as they are completely interchangeable. However, when a bushing is installed as a replacement it is recommended that the piston pin be used as a spotting mandrel for checking the bore in the bushing. Thickness gauges should also be used for checking the oil clearance between the pin and the bushing which should be from .0035 to .005 inches.

The old bushings may be removed from the connecting rod by means of an arbor press or a screw jack. The replacement may be installed in the rod by the same means.

It is recommended that a reference mark be scribed longitudinally on the outer surface of the bushing in line with the center of one of the radial holes which communicate between the inner and outer annular grooves. An additional reference mark should be stamped in the rod at one end of the bore, in line with the center of the oil hole in the rod. By keeping these marks in alignment when the bushing is being installed the selected radial hole in the bushing can be aligned with the rifle drilled oil passage in the connecting rod.

Piston and Connecting Rod Removal

1. Drain water from engine block and turbocharger (if used). Remove cylinder head.

2. Grease the tops of the pistons. This is done to catch the carbon which must be scraped from the tops of the cylinders before the piston can be removed.

3. If wear has produced a shoulder at the top of a cylinder bore, it must be relieved to prevent breakage of the piston rings as the piston is being pulled from the cylinder and to prevent ring breakage after new rings have been installed.

4. As each crankpin bearing is made ready for disassembly, it is suggested that the crankpin concerned be positioned at about 40 degrees from bottom center. Remove the cotterpins and bearing bolt nuts on that side. Rotate the shaft until the crankpin is about forty degrees on the other side of bottom center. Remove the cotterpins and nuts on that side and remove the cap and lower shell half. The crankpin must then be moved to approximately bottom center for the removal of the bearing bolts. Bearing bolts should be removed to avoid damage to the crankpin.

5. Rotate the crankpin to top center and bolt the lifting bow to the top of the piston and by means of suitable tackle pull the assembly from the cylinder.

   As soon as possible after the connecting rod has cleared the crankpin, the upper shell half must be removed. In addition, the connecting rod foot must be guided through the cylinder to prevent damage to the wall.

6. When removed, the piston should be placed on a pair of timbers, suspended between raised supports, with the rods hanging between the timbers and clear of the floor. The bearing caps, bolts. and shells should be replaced on their respective rods for safekeeping when more than one piston is pulled.

7. The rings should be removed, cleaned, and stacked in their proper order. Tags indicating the unit to which the rings belong should be attached to each stack.

8. To separate a piston from a rod, remove the piston pin covers by means of the puller which is furnished. Block up under the foot of the connecting rod so that the piston pin may be removed. Push the piston pin from the piston and lower the connecting rod to the floor. Remove piston from the connecting rod.

Piston Cleaning

Cleaning must not be delayed until the piston rings are stuck as compression then blows past the rings, resulting in removal of lubricant from walls of cylinders, which will cause undue wear of pistons, rings and liners.

Aluminum pistons should never be cleaned with emery cloth or sand paper.

If the railroad does not have the facilities to clean pistons by the Cold Method using Turco "Transpo" or Oakite Composition No. 16, or by the Hot Method using Sprex AC or Oakite No. 61, followed immediately with a hot water rinse, the piston will have to be cleaned by using paint remover or by scraping with a soft scraper.

Care should be taken to get the pistons, especially the ring grooves and the drain holes in scraper ring grooves, thoroughly clean.

Piston Ring Application

When applying rings to a piston, turn each ring completely around to be sure it has sufficient clearance and no tight spots. Make sure the upper side of the compression ring is stamped "top" as these are tapered face rings. Apply scraper rings with the scraping edge down. Check side clearance of all rings.

Piston Installation

When installing a piston in a cylinder, coat the piston and rings well with lubricating oil and see that the ring gaps are staggered by locating rings so that adjacent ring gaps are at least 120 degrees apart. The air valve pockets in the piston crown (1000 HP) should be assembled so that they are on the "A" side of the rod and the assembly (both 660 and 1000 HP) installed with the "A" side of the rod on the main camshaft side of the engine.

Piston Ring Break-In

After new piston rings have been applied, it is not necessary to idle the engine to "break-in" the rings. Experience has shown that there are no harmful affects resulting from placing the locomotive in normal service immediately following the installation of new piston rings.

MAIN BEARINGS

The main bearings are non-adjustable and no shims should ever be used. Therefore, whenever the main bearing clearances become excessive new bearing shells should be installed. When the crankshaft main journals become worn to the point where standard shells would provide excessive clearance due to scoring or other defects the journal can be ground to take a standard undersize bearing. If a crankshaft is proved to be sprung or broken it must be replaced.

Main Bearing Removal

The upper main bearing shells can be removed by removing the bearing caps. The lower main bearing shells can be removed by inserting the main bearing shell removing tool in the crankshaft oil hole and rotating the crankshaft counterclockwise (when viewed from the generator end) which will cause the tool to push or roll the lower main bearing shell out. Upper and lower shells of the same bearing are interchangeable. When shells are removed inspect for cracks or looseness of shells in the bearing cap. If a bearing shell is loose in the cap it should be replaced. Bearing caps are line bored and are not interchangeable. If a complete set of shells is applied the shaft must be resting uniformly on all bearings.

Main Bearing Installation

When replacing main bearing caps (upper) make sure that the groove or the inside bore of the cap is diagonally opposite to a similar groove to be found on the main bearing saddle.

The main bearing shells are anchored in their respective caps and saddles by a tongue which is pressed out of the bearing shell into a dovetail or groove and this prevents either upper or lower shell from turning around the crankshaft, which would result in cutting off of the oil hole and oil supply to the main and connecting rod bearings.

Tighten the main bearing nuts with the off-set wrench and extension handle until the cotter pin holes line up with the nuts extremely tight.

Main Bearing Break-In

Inspect the bearings for excessive temperature after running the engine for two minutes, five minutes and twenty minutes.

CRANKSHAFT

Crankshaft Deflection

The crankshaft deflection should be checked after:

1. Installation of engine generator set.
2. Application of traction generator to engine.
3. Renewal of main bearings.
4. Installation of air compressor.
5. Installation of air compressor drive coupling.

Excessive crankshaft deflection may cause the following conditions:

1. Main bearing failures.
2. Noisy air compressor.
3. Noisy air compressor drive coupling.
4. Crankshaft failure.

Place crankshaft deflection gauge between each pair of crank webs and take four (4) different readings starting with each piston at bottom dead center and rotating crankshaft in direction of rotation (counterclockwise from generator end) noting gauge reading at each 90° of crank throw. Allowable limit of crankshaft deflection is a total of .002 inches at any two opposite points.

An excess of crankshaft deflection above the allowable limits at the generator end should be corrected by adjusting the spring tension under the pads of the main generator, by adding shims to or by grinding off some of the spring.

Checking Crankshaft Thrust

Place a bar behind No. 4 main bearing webs and move crankshaft in both directions to see if thrust bearing has a .009 - .015 inch clearance between flange of crankshaft and machined surface of No. 7 main bearing shell.

CAMSHAFT ASSEMBLY

The main camshaft, located in the lower part of the pushrod housing is composed of three sections which are bolted together in male and female joints. The coupling bolts are installed with reamed fits and the mated flanges form bearing journals 3 and 5 respectively.

Babbitt lined bronze bushings located in the transverse frames of the pushrod housing, plus a bronze bushing fitted in the main gear casing, support the shaft which extends the entire length of the engine.

Each section of the shaft carries integral cams which actuate the inlet and exhaust valves by means of the lifter bracket, pushrod and rocker-shaft assemblies.

Longitudinal movement of the shaft is limited by the thrust bushing which, provided with thrust collars in halves, is located in frame at the drive end.

The camshaft gear, located in the main gear train, is installed on the shaft with a tapered fit. It is held in place by a heavy key and the camshaft gear nut. The nut is prevented from backing off the shaft by a large steel cotter pin. The gear is interchangeable with the fuel pump drive shaft gear.

If sufficient space has been provided in the engine room, the assembled shaft may be worked into position from the free end of the engine but if space is not available, installation must be made by section.

Camshaft Timing

In these engines the camshaft is designed with a very gradual lift at the beginning and end of the valve opening and consequently, a small error in measuring the beginning or ending of the lift results in a large error in the determination of the crank angle. For this reason the following procedure is recommended.

Remove the pushrods of No. 1 cylinder. In the pushrod lifter of the air cam, insert a 1/4" - 20" capscrew into the threads provided in the hardened bushing in which the pushrod ordinarily rests. Make sure that the pushrod lifter is free and that the roller is riding on the base circle of the cam — in other words, at a point diametrically opposite the peak of the cam. Adjust a dial indicator, with its pointer on the head of the capscrew previously described, at zero while the roller is on the cam base circle.

Bar the engine in the normal direction of rotation until the dial indicator reads .187 inch lift. If the reading of .187" is passed, the shaft should be backed off at least 45° and brought up to the reading .187" again which will eliminate the effect of backlash in the gear train. This should give a crank setting of 26.5° after top center on non-turbocharged engines and on turbocharged engines a crank setting of 38.5° before top center. This measurement can be made by means of a protractor placed on one side of the No. 1 crank web if the engine is known to be level.

The exhaust cam of No. 1 cylinder is treated in exactly the same manner, but the protractor reading on the crank web will be 4.5° before bottom center in this case. This should establish that the camshaft is properly timed. However, checking of the other cylinders in a similar manner may be done to further satisfy the maintainer and to check the possibility of cam wear which might throw off the valve timing. All the other cylinders should give the same readings with respect to their crank angle as the air and exhaust cams of No. 1 cylinder.

Remove the capscrews from the pushrod lifters and reinsert the pushrods.

GEAR TRAIN

The main gear train consists of a crankshaft gear, idler gear, main camshaft gear and a fuel pump drive shaft gear, Fig. 47-3.

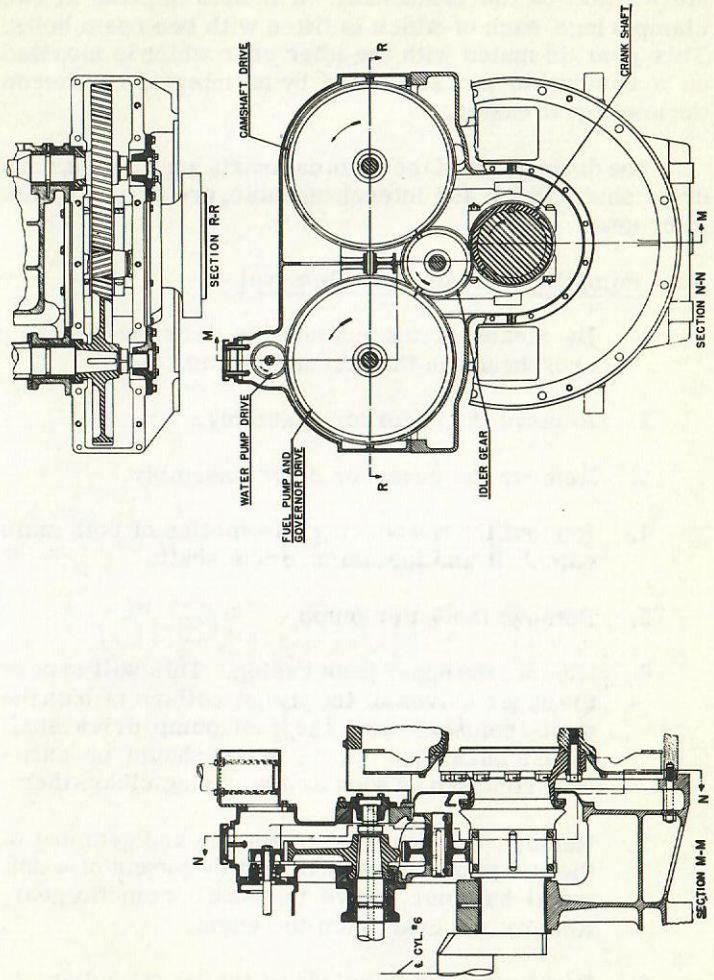


FIG. 47-3
GEAR TRAIN

The crankshaft gear, made in halves, is very accurately fitted to the crankshaft. It is held in place by two clamp rings each of which is fitted with two ream bolts. This gear is mated with the idler gear which is mounted on a removable pin supported by an integral bracket on the lower gear casing.

The drive gears of the main camshaft and fuel pump drive shaft, which are interchangeable, are driven by the idler gear.

Fuel Pump Drive Shaft Gear Removal

1. By means of the cutout pins, lock the fuel pump crossheads in the cutout position.
2. Remove the governor assembly.
3. Remove the governor drive assembly.
4. Remove the end bearing assemblies of both main camshaft and fuel pump drive shaft.
5. Remove the water pump.
6. Remove the upper gear casing. This will expose the upper halves of the thrust collars of both the main camshaft and the fuel pump drive shaft thrust bushings. These parts should be carefully removed as soon as the casing clears them.
7. Remove the gear nut cotter pin and gear nut of the fuel pump drive shaft and by means of a soft metal hammer, drive the shaft from the gear. Remove the gear from the engine.
8. Remove the lower halves of the thrust collars of the fuel pump drive shaft thrust bushing and work the shaft toward the free end of the engine until the gear end clears the thrust bushing flange.

Camshaft Gear Removal

1. Remove the pushrod housing doors.
2. Back off the valve lash adjusting screw and remove the pushrods.
3. Swing the pushrod lifters clear of the cams.
4. Remove the gear nut cotter pin and gear nut from the main camshaft.
5. Using a soft metal hammer, drive the camshaft clear of the gear.
6. Remove the gear from the engine and after removing the lower halves of the thrust collars of the main camshaft thrust bushing, move the camshaft toward the free end of the engine until the gear end clears the thrust bushing flange.

NOTE: The main camshaft and the fuel pump drive shaft may be moved into or out of position without disturbing their bushings by carefully working the cams through the bushing bores.

Idler Gear Removal

1. Disconnect the lubricating oil supply line from the idler gear bracket.
2. Remove the lower gear casing dowels and bolts.
3. Lift the lower gear casing assembly which includes the idler gear from the engine.
4. The idler gear can then be removed from the lower gear casing by removing the clamp bolts and driving the pin from the bracket.

Crankshaft Gear Removal

1. Remove the oil catcher casing from the generator end of the main base. Also remove the main base doors at No. 6 crank. These openings provide additional access to the crankshaft gear.

2. After taking precautions against damage to the gear teeth, remove the clamp bolts and the gear clamp rings.

3. Carefully remove the gear halves. It may be necessary to tap the keyed half free. Use a block of wood or lead maul.

Replacing Idler Gear

The idler gear may be replaced without removing the lower gear casing if it is only necessary to replace this part. Before removing any gears bar the engine over until all gears line up with the timing marks on the gears. Remove the fuel pump drive shaft gear. Remove perforated cover between the generator and the gear casing. Remove as many sections of the generator fan as is necessary or the generator if a solid fan is used. Remove the top half of the oil catcher sealing the generator end of the crankcase. Remove one of the vent covers on the side of the base. From these two openings it is possible to remove the ream bolts holding the idler gear shaft to the lower gear casing. Slide the shaft out of the idler gear but be careful not to lose the thrust washers, one at each side of the gear. As the shaft moves out these washers may be collected as they are released.

The idler gear is now in mesh with the crankshaft and camshaft gears and is free to turn out by barring the engine over in the direction of rotation. Before turning the engine the camshaft gear should be blocked to prevent it from turning. The idler gear can now be turned out and removed from the engine. The replacement idler gear should be started with the timing mark

in line with the mark on the crankshaft gear, then bar the engine in the reverse rotation until the gear is in place. Before turning engine any further determine by counting the number of tooth spaces on camshaft and idler gear from the mesh point to see if they will come together. The idler gear may then be installed on its shaft. Otherwise the camshaft gear has moved and it will be necessary to bring it to a position where the markings on the camshaft and idler gears will come together. Reassemble the idler gear to its shaft with a total end clearance between one of the thrust washers and the face of one of the idler gear bushings of .012 inches to .030 inches. Bar the engine over until the piston nearest the gear train is on top dead center of the compression stroke. The timing marks on the camshaft gear and the idler gear should come in line. Reassemble the fuel pump drive shaft gear with its timing mark in line with the one of the idler gear.

Reassembly and Timing of the Gears

1. Install the crankshaft gear with a butt clearance of .0015 inches at the leading joint of the unkeyed half. No clearance should be allowed at the opposite joint. The clamp ring bolts should be installed with a one man pull on a fifteen inch wrench.

2. Rotate the crankshaft until the marks on the crankshaft gear are at top center.

3. Install the lower gear casing and idler gear assembly and mesh the idler and crankshaft gears at the marks which are stamped in the unit.

4. Turn the crankshaft until No. 6 crank is at top center, at which point the respective pairs of double marks on the idler gear are in position to be mated with the single marks provided on the main camshaft and fuel pump drive shaft gears.

5. Mesh the main camshaft gear with the idler gear at the marked teeth and work the camshaft, with the gear key installed, into the drive gear. Secure the gear in position on the shaft by means of the gear nut and steel cotter pin.

6. Mesh the fuel pump drive gear with the idler gear at the marks provided and work the shaft into the gear and secure in a manner similar to that described in paragraph "5" above.

7. Install the thrust collars of the main camshaft and the fuel pump drive shaft thrust bushing.

8. Install the oil catcher casing with new gaskets and then install the upper gear casing.

9. Install the end bearings of both the main camshaft and the fuel pump drive shaft.

10. Install the water pump.

11. Reinstall the governor drive assembly and the governor.

12. Release the fuel injector pump crossheads by withdrawing the cutout pins.

13. Return the pushrod lifters to their proper location on the cams and reinstall the pushrods. Set the valve clearance at the tappets of both the air inlet and exhaust valves at .016 inches.

14. Replace the doors of the push rod housings and also those of the crankcase, completing the reassembly of parts.

NOTE: (1) Care must be taken when reassembling the gears to see that there is adequate backlash or gear clearance as shown on the Table of Clearances. Too small a clearance will cause binding of the gears and excessive wear.

(2) All gear casings and covers are dowelled to aid in assembling. Under no circumstances should lacquer be used to replace a gasket or vice versa.

OIL SLINGER

The slinger is made in two halves. If at any time there should be evidences of oil leaking out around the oil slinger, the condition should be immediately remedied so as to prevent oil getting on the main generator windings.

Oil leakage could be caused by either leaky joints at the slinger or by an excessive crankcase pressure condition.

If leakage appears to be resulting from excessive crankcase pressure, the crankcase vents should be checked as described in the following section and also for excessive piston blow by.

Leakage resulting from a poor fit at the slinger joints can be determined by trying a feeler gauge in the joints. If a .0015 feeler can be inserted the assembly should be dismantled and the surfaces spotted in. All joints are metal to metal fits with "osolite" or similar oil resistant lacquer and used as a sealing compound.

Access to the slinger is had by removing the generator fan sections and the vent covers on either side of the engine base. The assembly can then be removed in two halves.

CRANKCASE VENTS

There are several crankcase vents located at various points on the Diesel engine. If the vents should clog,

excessive crankcase pressure might develop and cause oil leakage at various parts of the engine, such as at the crankshaft oil slinger. If this is the case the vents should be disassembled and the oil separating screens in them should be washed out.

660 H.P. engines have a vent at either side of the engine base located just ahead of the generator and a third vent pipe located at the front of the engine and leading from the crankcase to the air intake manifold.

1000 H.P. engines have vents just ahead of the generator at either side of the base. A third vent pipe leads from the water pump drive gear casing to the turbocharger intake as shown on the illustration of the gear train.

TURBOCHARGER

Introduction

The 1000 H.P engine operates with a turbine driven supercharger The turbocharger installation was especially developed for locomotive service where rugged construction and reliable operation are of utmost importance. Certain alterations have been made in the standard Diesel engine to adopt it to the use of the turbocharger. These include changes in the combustion chamber, fuel injection system and valve timing. The air and exhaust manifolds have also been modified to suit the turbocharger. The exhaust muffler has been removed from its position above the generator and the turbocharger put in its place.

After exhaustive tests of the turbocharged engine, a conservative rating has been established as standard. This rating is made possible without materially adding to the bearing pressure, but with better fuel economy and lower running temperatures. The greater volume of air used in scavenging the engine keeps the temperature of the cylinders moderate, making it possible to maintain an adequate oil film on the cylinder walls.

Principle of Operation

The operating cycle of the engine remains the same with the exception of the exhaust and suction strokes of the cycle.

The camshaft of the engine is designed to allow the opening period of the air and exhaust valves to overlap to a greater extent than the standard four-cycle engine. This permits the scavenging air to clean out the exhaust gases in the cylinder near the end of the exhaust stroke and to cool the combustion chamber of the engine. A much lower pressure in the exhaust manifold than is present in the air manifold is necessary to insure sufficient flow of scavenging air through the combustion chamber for complete scavenging. This low pressure is attained by providing two exhaust manifolds, each being supplied by three cylinders which conduct the exhaust gases into the exhaust gas turbine casing at two separate points. By doing this it is possible to have a pulsating pressure which has a minimum value during the period of overlapping of the air and exhaust valves. At this time the exhaust pressure is much lower than the air inlet pressure. This permits the clean cool air to scavenge the combustion chamber thoroughly.

The scavenging system described above makes it possible to trap a much larger quantity of clean air in the combustion chamber at the beginning of the compression stroke. A larger quantity of fuel oil may be burned thereby taking a fuller advantage of the engine's volumetric capacity than is possible on the standard four-cycle Diesel engine.

Description

The turbocharger, Fig. 48-3, consists of a centrifugal blower driven by an exhaust gas turbine. Both blower and turbine are mounted on a common rotor shaft and

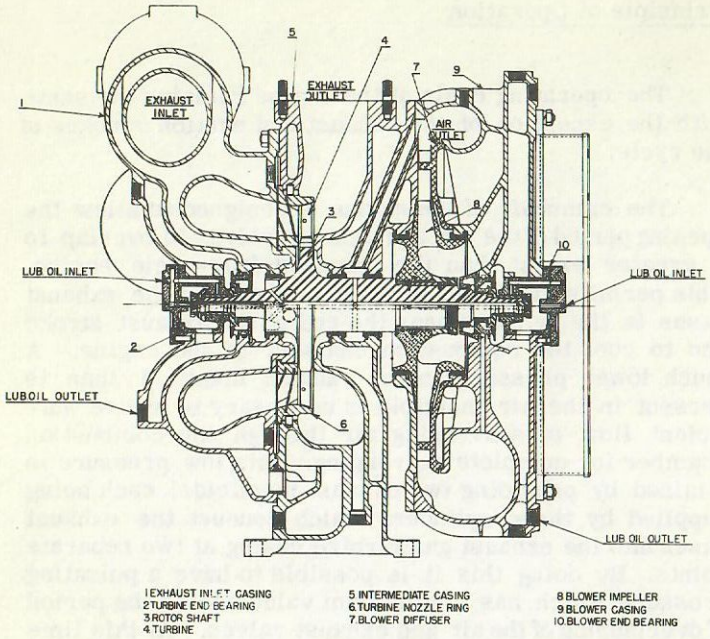


FIG. 48-3
TURBOCHARGER

separated by a water cooled diaphragm. Labyrinth rings are provided to seal the individual air and exhaust chambers to prevent contamination and pressure losses.

The speed of the turbocharger is dependent upon the volume and temperature of exhaust gases produced by the engine. Consequently, the turbocharger is directly controlled by the load on the engine and automatic control of the turbocharger is thereby provided.

The blower casing is divided at the centerline of the shaft into upper and lower halves. The casing is securely bolted to the other parts of the turbocharger housing. One of the two rotor shaft bearings is carried in a housing mounted in the blower casing. The impeller is housed in a suitable shaped space in the blower casing and the

outer rim of the impeller is surrounded by the stationary, bladed diffusor. Axially converging entrance passages surround the bearing housing. The air flows from these passages into the impeller and is discharged from the impeller to the diffusor. The blades in the diffusor are shaped to decrease the velocity of the air and at the same time increase its pressure. The air discharged radially from the diffusor is collected in a spiral chamber and delivered to the air manifold of the engine through a connecting pipe.

The central portion of the turbocharger is made up of two castings with the dividing line on the horizontal shaft centerline. The lower half has an integrally cast foot for mounting the entire assembly on its foundation. A large opening in the upper half provides the connection to the exhaust stack. On the exhaust side, a nozzle ring is mounted on the exhaust casing which serves to direct the exhaust gases against the turbine blades at the proper angle.

The turbine blades rotate within the rim of the nozzle ring. Gas from the nozzle ring flows across the blades and leaves the blades in an axial direction. The collection and discharge chamber which is part of this central portion is provided with water cooled walls throughout.

The turbine consists of a forged steel, one-piece shaft, mounted in bearings at each end. The air impeller, described above, is fitted near one end of the shaft. The turbine rotor is a large integral flange, near the other end of the shaft in which the turbine blades are fitted and locked. A lashing wire passes through a hole in each blade and is silver soldered in place. The wire is made in several lengths so that groups of 3, 4 or 5 blades are independent of adjacent groups.

The turbine nozzle ring is divided at the horizontal centerline and has a flange on the exhaust inlet casing side which fits into a counterbore in the intermediate casing. There is a small clearance between this flange

and the exhaust casing. There are two separate nozzles in this assembly which are independently connected to the upper and lower exhaust manifolds, respectively, through passages in the exhaust inlet casing. In each of the nozzle ports there are eight cast-in steel vanes.

The exhaust inlet casing is provided with suitable passages for conducting the exhaust gases from the manifolds to the nozzle ring. It is made of cast iron and is water jacketed. In Assembly the casing halves are bolted together at the horizontal centerline and also to the intermediate casing. The exhaust end shaft bearing is carried in a housing mounted in this casing.

The rotor is carried at both ends by sleeve bearings. The bearing at the turbine end is a combined supporting and thrust bearing for fixing the axial position of the shaft. The bearing at the blower end is arranged to allow free expansion of the shaft by heat. The journals are hardened steel sleeves which may be readily replaced.

Labyrinth glands are provided throughout to prevent the contamination of the gases. End bearings are machined in the form of a bushing making replacement a simple matter.

Typical Performance Data of Turbocharger

Volume of indrawn air, measured in suction branch	3420 Cu. Ft./Min.
Suction pressure, measured in suction branch	-.32/In.^{2} Approx.
Charging pressure, measured in delivery branch	5.0#/In.^{2} Approx.
Approx. blower speed at full load	10,000 RPM
Approx. blower speed at engine idling speed	2,200 RPM
Max. blower speed	13,000 RPM
Max. pressure of exhaust gases after turbine	Atmospheric
Approx. exhaust gas temperature after exhaust valves	800° F.
Approx. exhaust gas temperature before turbine	900° F.
Max. allowable temperature before turbine	1020° F. Continuous 1100° F. Momentary

Clearance:

Bearings:	Running	.006" to .008"
	Thrust	.008" to .012"
Shaft:	Radial Clearance	
	Labyrinth, turbine end bearing	.009" to .011"
	3 Center Labyrinths	.009" to .012"
	2 Blower hub labyrinths	.015" to .022"
	Inner blower end labyrinth	.008" to .013"
	Center blower end labyrinth	.008" to .012"

Blower Impeller:

Axial clearance between impeller and center housing	1/16"

Operation

If the blower speed or the charging air pressure drops under the normal values, or if there are indications of abnormally high temperature, immediately reduce the engine speed and ascertain the cause of the trouble. This may be due to:

1. Failure of the fuel injection system or other trouble with Diesel engine (i.e., leaky exhaust valves, excessive blowby, stuck nozzles, etc.)
2. Losses from leaky joints in air delivery piping.
3. Losses in the exhaust gas piping between the Diesel engine and the turbine.
4. Excessive restriction in air filter.
5. Trouble with blower assembly. (Bearing troubles, rubbing of packing gland or turbine wheels, etc.)
6. A poor connection in generator field resistance or the slipping of exciter belts.

If the turbocharger vibrates abnormally, the cause should be found immediately and rectified. The vibration might be caused by a disturbance of the rotor balance combined with too much clearance in the bearings or damage or loss of a turbine blade, or a portion of the air impeller.

The free running time of the rotor, after stopping the Diesel engine, should be checked from time to time. This gives an indication of the bearing condition. The free running time from 2200 RPM of the turbocharger (engine idling) to a standstill is approximately three minutes.

Lubrication

The turbocharger bearings are lubricated by oil taken directly from the engine lubricating system.

The oil is drained from each bearing into the engine and recirculated through the system.

Dismantling

Before attempting to dismantle the turbocharger the cooling water should be drained and all the lubricating oil piping dismantled. The two exhaust pipe connections must be disconnected and the stack connection removed. Clear space above the turbocharger is essential. The two shaft end covers may now be removed. Remove all the bolts along the joint on the horizontal centerline. The three sections of the upper casing may now be removed as one unit by lifting straight upward with the two eye-bolts provided for this purpose.

This operation will expose the turbine wheel and blower impeller, all the upper labyrinths, diffuser, and nozzle ring for inspection.

To remove the turbine end bearing it is necessary to remove the shaft end nut, lockwasher and thrust washer. The bearing may then be gently removed axially. If done easily the shaft will settle onto the labyrinths with no damage.

To remove the blower end bearing simply remove the shaft end nut and locknut and slide the bearing out axially. If done smoothly and easily the shaft will settle onto the labyrinths without damage. When both bearings are removed the shaft and rotors can be lifted out of the lower casings.

In order to remove the nozzle ring and diffuser halves it will be necessary to unbolt the outer casing halves on each side of the center section. The nozzle ring and diffuser can then be removed without further dismantling.

Inspection and Maintenance

The blower should be dismantled at each annual inspection. The following points should be carefully checked:

Blower

Does the impeller fit firmly on the shaft and are there any signs of contact on the outer periphery or on the inlet ring?

Rotor Shaft

Are there any signs of contact caused by the labyrinths? Pitted running surfaces should be refaced. The surface under the labyrinth rings are to be examined at least once a year for corrosion.

Turbine Wheel

Are any of the blades broken or bent and are the inlet edges still sharp? Have the blades become badly worn or has the wheel been touching any point? Is there any sign that foreign matter has passed through the wheel? If blades are damaged in any way the complete rotor should be returned to the manufacturer for rebalancing.

Nozzle Ring

Has the ring a firm fit and has it warped? Are there any signs of contact with the tips of the turbine wheel blades? Is there any foreign matter lodged between the nozzle plates and have any plates worked loose, been burned, cracked, or bent? If plates are bent or broken, return to the manufacturer for repair.

Bearings

Is there any discoloration of the bearings due to

overheating? Are any defects visible or do the running surfaces indicate that foreign particles have been rolled in them? Have the bearings received sufficient lubrication and are there any signs of excessive wear? Check the running clearances of the bearings to the proper figures given under Turbocharger Data.

Labyrinths

Check the labyrinths to see if any dirt has entered and see if the clearance has been affected by wear or corrosion by exhaust gases. Have any of the rings been bent or damaged in service or when assembling? The impeller labyrinth rings should be inspected to see if the sealing air inlet is clean.

Diffuser

The diffuser is to be checked for cleanliness, position and general condition.

Casings

Check the turbine and impeller casings for any signs of leakage or large accumulations of dirt caused by oil, water, scale, dust or carbon accumulations.

To Reassemble

Reverse procedure described under "Dismantling" taking care in the handling of the rotor to prevent damaging of the labyrinths. After replacing the shaft and bearings be absolutely sure to check the thrust bearing clearance at the turbine end. After the three upper casing halves have been replaced be absolutely sure to check the clearance between the turbine runner and nozzle ring. This is accessible through the stack connection.

The bearings are to be carefully checked at the annual inspection. If necessary new bearings and sleeves should be installed.

ENGINE RUNNING-PROCEDURE

After a complete overhaul the engine should be run-in as follows:

1. Idle engine 1 minute, then inspect bearings.
2. Idle engine 5 minutes, then inspect bearings.
3. Idle engine 30 minutes, then inspect bearings.
4. Place the locomotive in light switching service for eight hours.
5. Place locomotive in regular service.

WATER BOX INSTRUCTIONS

These instructions are based on the use of a water box of capacity enough to absorb the output of the 660 or 1000 HP low hood type of locomotive.

PREPARATIONS

1. Idle engine 1 minute, then inspect bearings.
2. Idle engine 5 minutes, then inspect bearings.
3. Idle engine 30 minutes, then inspect bearings.
4. Disconnect cable GA to A4 at GA and tape up loose end. Do not disconnect GA to SP2 as engine will not start.
5. Disconnect cable SP2 to A2 at SP2 and tape up loose end.
6. Disconnect cables EF to CL and EF to J3 at the exciter and tape up the loose ends.

7. Open up the ground relay circuit at J3 and connect into the negative side of the generator at EF.
8. Using two 1325/24 cables or equal, connect positive side of loading apparatus through a circuit breaker to GA.
9. Using the same cable capacity connect the negative side of the loading apparatus to EF through a shunt and ammeter capable of measuring 1600 amperes for the 1000 HP locomotive and 1400 amperes for the 660 HP locomotive for measuring generator current.
10. In measuring generator voltage a voltmeter capable of measuring 1000 volts should be connected across the main generator at EF and GA.
11. It is recommended that the two wheel slip circuits be opened up at SP2 to keep high potential from the motors.
12. A 150 volt voltmeter should be connected across the main generator shunt field at GS and GSS.
13. A 100 amp. millivoltmeter and shunt should be placed in the main generator field circuit between GS and GS.
14. A 150 volt voltmeter should be connected across the auxiliary generator. Make connections at fuse 103 positive and wire 65 for negative.
15. With the above connections for a load test, the control including the ground relay will operate normally.

Load Testing

1. Inasmuch as exciter field excitation and main generator loading are based on 75 volts auxiliary generator output at the voltage regulator at both

idling and full engine operation, it is advisable to have a small load while setting the voltage regulator.

2. Then the main and exciter generator should be warmed up under partial load until the resistance of the shunt field in the main generator (between GS and GSS) is about 0.8 ohms as measured by the ammeter and voltmeter in the exciter to main generator shunt field circuit.

3. The engine horsepower to the main generator (for traction) on the 660 HP locomotive should be set at 625 HP and on the 1000 HP locomotive should be set at 950 HP at 740 RPM. The fact that engine horsepower output referred to introduces generator efficiency, the engine horsepower delivered to the generator can be calculated from the following formula and curves which show the generator, generator efficiency and transfer relay characteristics.

$$\text{Engine HP Output} = \frac{E \times I}{746 \times \text{Gen. Eff.}}$$

E - Volts, Main Generator output
I - Amps, Main Generator current
1 HP - 746 Watts

4. Break-in engine for one hour duration at speeds and corresponding HP as indicated on the Generator Characteristic Curves.

5. For full load testing load the main generator starting in at 1400 amperes on the 660 HP locomotive, 1600 amperes on the 1000 HP locomotive. Always take generator characteristic readings starting at the high current end of the curve and proceed towards the "O" current end of the curve.

6. Adjustment of the generator characteristic and output can be accomplished as follows:

If the contour of the generator characteristic does not correspond in contour shown by the curve, being too high or too low at the high current end, the correction should be made as follows:

To raise the high current portion of the curve, decrease the amount of exciter field resistance in the separately excited circuit between R6 and R7.

To lower the high current portion of the curve, increase the amount of exciter field resistance in the separately excited circuit between R6 and R7.

If the contour of the generator characteristic does not correspond in contour shown by the curve, being too high or too low at the low current end, the correction should be made as follows:

To raise the low current portion of the curve, decrease the exciter field resistance in the self excitation circuit between R5 and R6,

To lower the low current portion of the curve, increase the exciter field resistance in the self excitation circuit between R5 and R6.

The loadings should be as follows:

1000 HP locomotive - 950 Engine HP for traction at 22-1/2 mm rack travel and 740 RPM.

660 HP locomotive - 625 Engine HP for traction at 24 mm rack travel and 740 RPM.

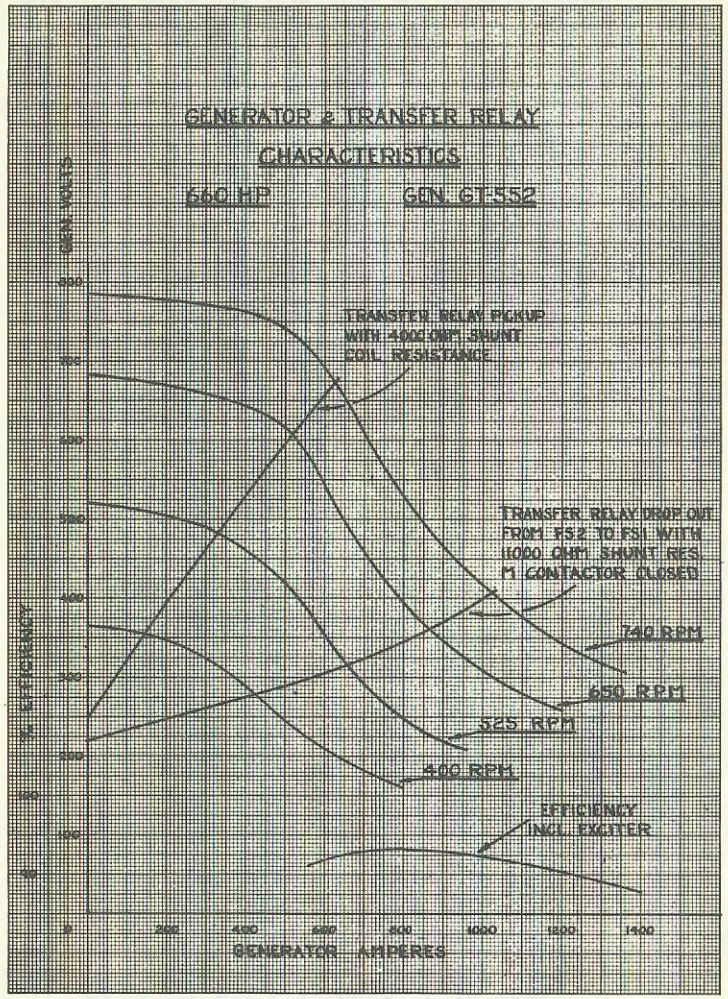


FIG. 49-3
GENERATOR AND TRANSFER RELAY
CHARACTERISTICS – 660 HP

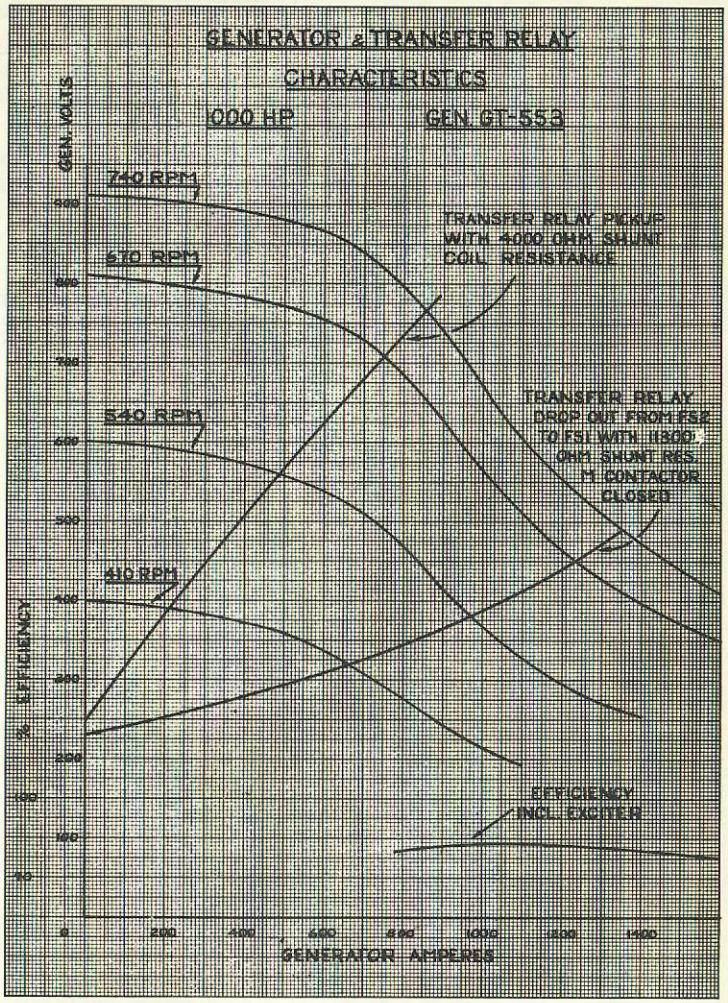


FIG. 50-3
GENERATOR AND TRANSFER RELAY
CHARACTERISTICS – 1000 HP

7. To check the transfer relay operation, adjust the loading device to obtain high current on the generator curve. Reduce the current slowly and note when transfer from series to series-parallel and series-parallel to shunt field takes place by watching the transfer relay (V relay) or the sudden kicking back of the voltmeter and ammeter needles. Refer to the relay pickup and drop out curves for points of operation. Adjustments are made by changing resistance at VR7.

   The controller should be placed in the shunt field position or the series holding switch in ON position.

FUEL OIL SYSTEM

DESCRIPTION

The fuel tank is located beneath the cab floor and an additional fuel tank is provided under the underframe on the Road Switcher. A fuel booster pump draws fuel from the tank and then distributes it throughout the system.

The suction side of the system is between the tank and the booster pump. All oil drawn from the tank must pass through the emergency fuel cutoff valve and the fuel oil suction filter before reaching the booster pump.

The pressure side of the system is between the booster pump and the pressure regulating valve which discharges excess oil back to the tank. As the fuel is discharged from the pump, the pressure is regulated by a valve which is set to maintain 35 to 40 psi. Oil from the pump first passes by a pressure relief valve set at 75 psi, the purpose of which is to protect the booster pump, motor and system from overload. Oil then passes through two Cuno type strainers and one felt type filter, which are housed in a single casing, to the fuel inlet manifold where the individual injection pumps deliver the fuel to the injection nozzles. On some locomotives this filter assembly has been eliminated and a throw away paper type substituted. The pressure regulating valve is located in the fuel return line from the manifold to the tank. Ahead of this valve is the line connecting to the fuel oil pressure gauge on the control stand gauge panel.

FUEL TANK FILLING

A sight gauge glass and a plate marked with approximate gallons is provided on the back, right side of the tank on the 660 and 1000 HP standard switchers to permit observation of the fuel level when filling and also for

periodic checks of the amount of fuel in the tank during operation, Fig. 1-5.

The tank is also equipped with a vent pipe and filling connection located near the gauge glass. The road switchers have fuel level gauges on the right and left side of the fuel tank and also remote reading fuel gauges located in the operating cabs.

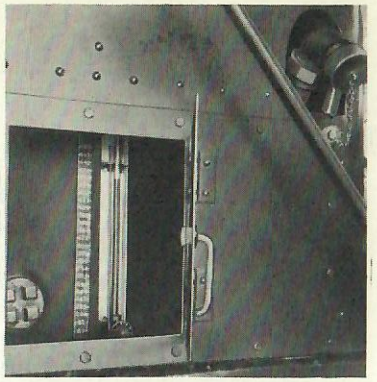


FIG. 1-5
FUEL OIL LEVEL GAUGE

FUEL TANK DRAINING

The fuel tank is equipped with drain plugs for clean-out purposes and a condensation drain valve leading from a well type sump located under the tank. This sump should be drained periodically and particularly if there is any evidence of water or sludge in the fuel.

In the event water is found in the fuel, the wayside fuel oil supply tank and the engine filtering system should be carefully checked immediately as water will cause extensive damage to the injection equipment.

DUPLEX FUEL FILTER

The duplex fuel filter, Fig. 2-5, located in the suction line to the booster pump, consists of two filtering elements each containing one pound of filter-

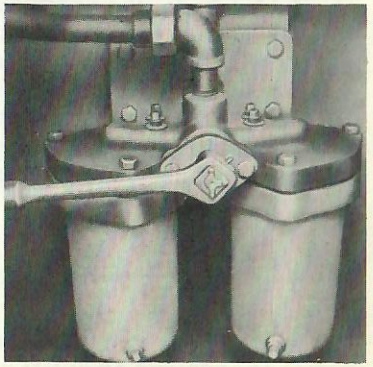


FIG. 2-5
DUPLEX FUEL FILTER

ing material on the road switcher locomotive and 6 ounces on the 660 HP and 1000 HP standard switcher locomotives.

The filter handle controls the flow of fuel through either one of the two elements or both. With the handle in a horizontal position, one element is in use; with it in the vertical position, both elements are in use. Normal position for the handle is horizontal. With the handle in a 45 degree position, no fuel will flow through the filter.

If there is a gradual drop in fuel pressure, the indication is that the element in use is plugging and the handle should be moved to the opposite horizontal position. The dirty element may be repacked with the engine running.

FUEL FILTER AND STRAINER ASSEMBLY

The fuel oil filter on the engine, located in the discharge line from the booster pump, is a combination of two Cuno strainers and one felt type filter, Fig. 3-5. The oil is passed through the Cuno strainers where most of the impurities are removed. To insure the removal of even finer foreign particles, the oil is then passed through the felt filter and on to the fuel pump inlet manifold. The complete filtering unit is assembled in a single casing. The oil is passed from one unit to the other by means of passages in the casing cover. The casing forms the sump for the sludge which can be easily drained by removing the drain plugs.

The CUNO strainer cartridge consists of a stack of round, perforated discs, each separated from the other by a very thin metal spacer. The thickness of the spacer determines the fineness of filtration. The first of these two Cuno strainers has a .005 in. spacer while the second has a .003 in. spacer.

A turning handle is provided which revolves the cartridge against stationary cleaning blades. These

blades extend into the cartridge through the filter slots. The handle should be turned clockwise so that the cleaning blades scrape the filter slots clean and force the sludge into the sump where it should be removed monthly.

The time intervals between the turning of the cartridge will vary due to operating conditions. However, the handle may be turned frequently as there is nothing to wear out, nothing to replace.

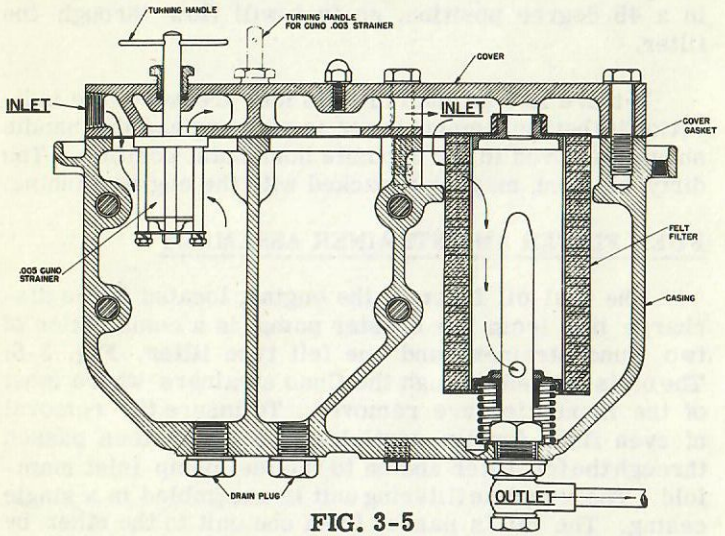


FIG. 3-5
FUEL FILTER AND STRAINER ASSEMBLY

Do not turn with a wrench or other tool if the strainer becomes plugged. Under such circumstances the cartridge should be removed and washed in a solvent until it turns freely.

The FELT filter consists of a group of felt pads mounted on a perforated cylinder. The fuel oil passes from the .003 in. Cuno strainer to the outer walls of the felt pads. The oil filters through the felt into the perforated cylinder, where it is piped to the fuel pump manifold.

The amount of impurities escaping the Cuno strainer cartridges is almost negligible, making replacement of the filter cartridge indefinite.

To remove the cartridge, merely remove the strainer casing cover and withdraw the unit. This lifts off the outlet stud. The new cartridge can now be installed. Replace the cover and the filter is ready for service.

FUEL FILTER

On some locomotives the fuel filter and strainer assembly has been replaced by a single type paper element filter, Fig. 4-5. When there is a gradual drop in fuel oil pressure and it cannot be remedied by changing the handle position on the duplex fuel filter, replace the element in the single fuel filter. These elements are furnished complete with gasket and spring permanently attached.

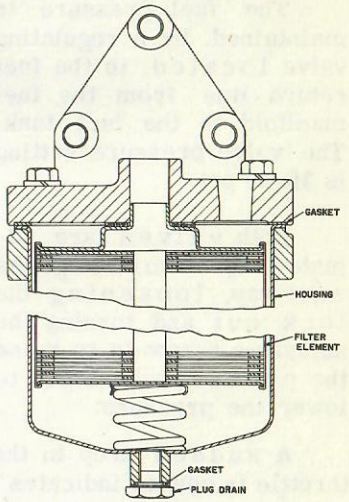


FIG. 4-5
FUEL FILTER

FUEL BOOSTER PUMP

This consists of a gear type pump direct driven by a 1/4 HP motor through a flexible coupling and its function is to keep the fuel injection pumps supplied with fuel oil at all times.

RELIEF VALVES

A relief valve is located in the fuel line between the fuel booster pump and the engine filters, Fig. 5-5. The

valve is set at 75 psi and normally does not function. In case the filter clogs or fuel flow stoppage occurs from other causes, it protects the pump and motor against overload.

The fuel pressure is maintained by a regulating valve located in the fuel return line from the fuel manifold to the fuel tank. The valve pressure setting is 35-40 psi.

Both valves are adjusted by removing the valve cap, loosening the lock nut and turning the adjusting screw in to raise the pressure and out to lower the pressure.

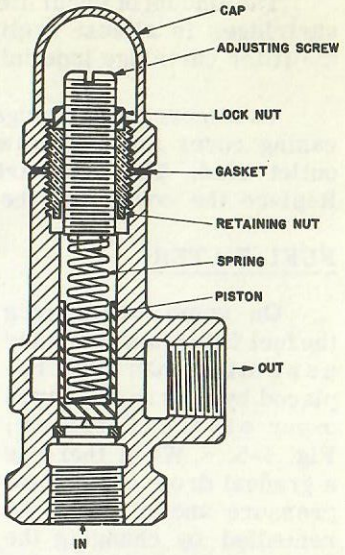


FIG. 5-5
RELIEF VALVE

A sudden drop in the fuel oil pressure when the throttle is opened indicates a sticky pressure regulating valve.

Normally no priming of the fuel system is necessary as the pressure regulating valve will vent the system when the booster pump is started. However, occasionally fuel lines do become air bound and it is then necessary to bleed the air from the lines by loosening the bleeder screw on each of the fuel injection pumps. This condition is reflected by rapid fluctuation of the needle on the fuel oil pressure gauge.

FUEL DRAINAGE SYSTEM

For the purpose of conserving fuel and preventing dilution of the lubricating oil, the engine is equipped with a fuel drainage system.

A drain funnel is secured to the cylinder block on the fuel injection pump side. Leakage from the various units is piped to this funnel from which the main drain carries it through a swing check valve to the fuel tank.

The individual units are drained as follows:

Fuel Nozzles — Oil from the nozzle leak-off connections is drained through suitable pipes to the leak-off header which is provided with three risers, each of which receives the drainage from the nozzles of two cylinders.

Fuel Filters — A lip, cast in the body of the filter to form a groove, is provided to catch any oil that may leak past the gaskets or fittings of the filter head. From this groove a tube conducts the oil to the drain funnel.

Fuel Pump Housing — Drainage from the fuel injection pumps is collected in the housing and carried to the drain funnel by the upper housing drain pipe.

HIGH PRESSURE FUEL PIPES

The high pressure fuel pipes are the lines leading from the individual injection pumps to the fuel nozzles in each cylinder head. If, due to improper tightening of the joints or other cause, a pipe should develop a leak, the cylinder with the leaky pipe should be cut out immediately. If the pipe should be leaking inside the rocker box, fuel oil will be mixed with lubricating oil resulting in crankcase oil dilution. Dilution can be detected by low lube oil pressure or by an increase in the level of the crankcase oil as shown on the gauge. Crankcase oil should be drained when a maximum of 5% fuel dilution is found.

It is not allowable to operate an engine with diluted crankcase oil.

FUEL INJECTION PUMP CUTOUT

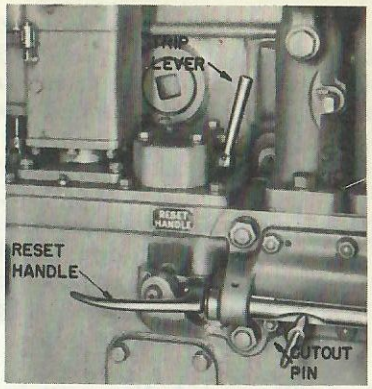


FIG. 6-5
PUMP CUTOUT

Disengage injection pump cutout pin of that cylinder from the overspeed trip rack by pulling out cutout pin and turning it. Turn the finger downward until the dog of the cutout pin falls in the slot cut in the injection pump casing, Fig. 6-5. The pin then moves in engaging the injection pump crosshead and holds the pump plunger mechanism of the injection pump drive camshaft.

It is permissible to operate at full throttle with one cylinder cut out.

FUEL PROBLEMS

Fuel Oil Pressure Drops

1. Check fuel oil supply.
2. See that fuel pump is running.
3. See that emergency fuel cutoff valve is open.
4. Move handle of duplex filter in control compartment to opposite side to make sure filter is not clogged. Report this to maintainer.
5. Rotate handles of Cuno filters on side of engine to make sure they are not clogged.

6. Check for leaks on suction side of fuel pump.
7. If the pressure drops when the throttle is opened and comes back up when the throttle is closed, check the fuel oil pressure regulating valve and the fuel oil by-pass valve for sticky cup valves.

Fuel Pump Does Not Run

1. See that fuel pump switch fuse is good.
2. See that 110 amp. fuse in control compartment is good.
3. Check fuel pump coupling.
4. Check fuel pump shaft for freedom of movement.

Hot Cylinder

If one cylinder is receiving too much fuel, its exhaust pipe elbow will be hotter than the others, may even become red hot. Cut out this cylinder and report to maintainer. By cutting out pumps individually this can be determined by sound. A "Fuel Ram" can be heard.

Cylinder Not Firing

The exhaust elbow of a cylinder not firing will be cooler than the others. Cut out this cylinder and report to maintainer. Check by cutting out one pump at a time to determine which cylinder is not firing.

Broken Fuel Pipe

If the fuel pipe from an injection pump to nozzle is broken, cut out that cylinder.

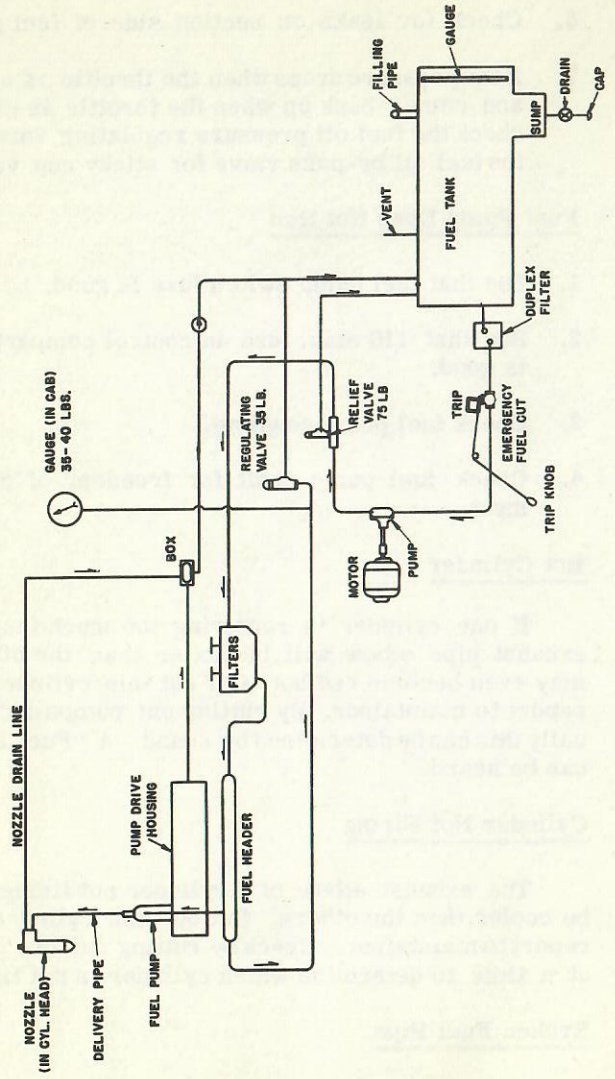


FIG. 7-5
FUEL OIL SYSTEM
660 AND 1000 HP SWITCHERS

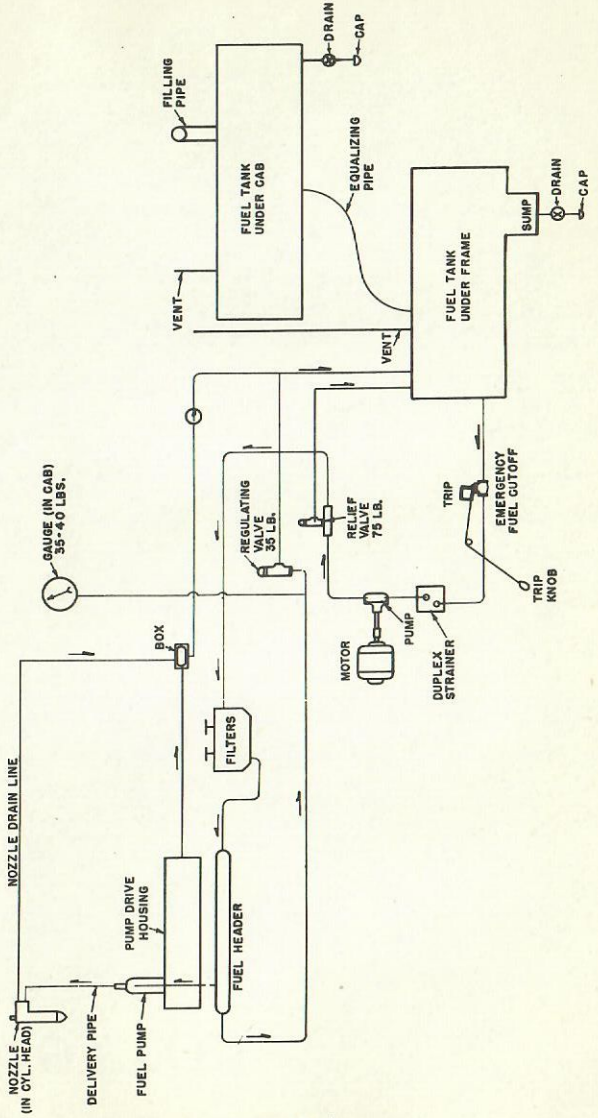


FIG. 8-5
FUEL OIL SYSTEM
1000 HP ROAD SWITCHER

NOTES

LUBRICATING OIL SYSTEM

DESCRIPTION

The engine is equipped with a lubricating oil pump located at the free end of the engine which is driven by the crankshaft through the lubricating oil pump drive assembly. The pump draws oil from the engine crankcase and discharges it under pressure to the oil radiators. This pressure is regulated by a pressure regulating valve mounted in the pump discharge line. Part of the oil from the radiators passes to the main oil header in the engine through Cuno filters which are contained in a common chamber in the end cover of the engine base. The rest of the oil flows through a 35 psi check valve, through one waste-packed filter on the 660 HP and 1000 HP standard switchers or two waste-packed filters on the 1000 HP road switcher and then into the oil sump of the engine base. A 15 psi differential pressure valve is located in a line connecting the radiator inlet pipe to the radiator outlet pipe. Shutoff valves are also provided in the radiator inlet and outlet pipes.

From the engine main header the different assemblies are supplied with lubricating oil through suitable connecting pipes and passages. Lubrication of the individual assemblies is described in the following under separate headings.

Main Bearings — Each of these bearings is supplied by an individual tube from the main header. These tubes have an OD of 5/8 in. and are adapted by means of SAE fittings.

Main Camshaft Bearings — With the exception of the end bearing, all bearings are individually supplied by 1/4 inch line which also supplies the Fuel Pump and Governor Drive Assembly and the Turbocharger, if the engine is turbocharged.

Lubricating Oil Pump Drive — A single 3/8 inch tube leading from the main header supplies oil to this assembly which has suitable passages for conducting the lubricating oil to the various bearing surfaces. A 1/2 inch tube at the bottom of the casing returns the drainage to the crankcase.

Valve Operating Mechanism — The valve operating mechanism of each cylinder unit is supplied by a 1/4 inch tube which provides passage from the main header to the lifter bracket. The oil flows through passages in the parts of the assembly and lubricates all bearings and bushings. Lubrication of the valve springs and guides is provided through a metering valve located on top of the exhaust valve rocker arm which sprays oil inside the rocker box.

Fuel Pump And Governor Drive Assembly — Oil is supplied through the 3/4 inch lead to the main camshaft end bearing where it passes through an annular groove to an outlet pipe which leads to a tee on the opposite side of the engine, one leg of which feeds the end bearing of the fuel pump and governor driveshaft.

Connecting Rod Assemblies — Rod bearings and piston pins are supplied with oil from the main bearings through passages in the crankshaft and connecting rod.

Main Gear Train — A 3/8 inch tube supplies the idler gear from the main header through a passage in the idler gear bracket which communicates with the annular space between the gear shaft and the gear hub and drilled passages in gear shaft. Four radially drilled holes communicating between the annular reservoir in the idler gear hub and the gear teeth, provide lubrication for the mating gears, namely, the fuel pump drive shaft gear, the main camshaft gear and the two piece crankshaft gear. An oil lead to the water pump gear is not necessary

because it mates with the lubricated teeth of the fuel pump drive shaft gear.

FILLING AND DRAINING

To fill the system, any engine base door can be removed and the oil poured in through this opening. A filling hole is provided in the base at the free end of the engine for the addition of make-up oil. Never remove a base door while the engine is running as hot oil, thrown from the rotating parts, may cause personal injury and also could result in engine damage due to a crankcase explosion.

To drain the system, remove the pipe cap from the external drain pipe and open the drain valve in the external drain pipe.

A bayonet gauge, located in the base of the engine on the left side is provided with a HIGH and LOW mark to determine when oil should be added to the system. The oil should be checked daily with the level maintained between the high and low mark, preferably at the high, with the engine idling on a level track.

Whenever the oil is changed the base should be washed and wiped out thoroughly with clean rags.

LUBRICATING OIL PUMP AND DRIVE ASSEMBLY

This assembly is comprised of the lubricating oil pump and the lubricating oil pump drive assembly which transmits rotary motion from the engine crankshaft to the pump. Both the pump and the drive are first assembled as individual units and are then bolted together and mounted on the end cover of the main base. In the following, each unit is described separately.

Lubricating Oil Pump

This pump consists of a pumping element of the helical gear which is housed in a bronze casing assembly made in two sections. The casing sections are joined together in metal to metal fits and the parts are held in assembly by studs and ream bolts. The uppermost section of the pump is provided with a flange by means of which the pump assembly is secured to the drive casing.

The upper end of the pump driveshaft is machined to engage the spline coupling which connects the pump shaft to the vertical shaft of the drive assembly.

The pump has a capacity in excess of actual requirements and the surplus is discharged to the sump through a built-in spring loaded relief valve set at 75 psi.

Lubricating Oil Pump Drive

This assembly transmits rotary motion from the crankshaft to the lubricating oil pump.

Rotary motion is transmitted to the pump in the following manner. The head of the drive pin which serves as a crank is positioned between two hardened steel buttons which are fitted to a pair of lugs on the face of the crankshaft bearing ring. As the crankshaft revolves, the head of the drive pin is carried with it causing the horizontal shaft of the drive assembly to rotate. The drive gear which is meshed with the gear on the vertical shaft, causes this shaft to turn. A spline coupling connects the vertical shaft to the pump drive shaft.

When the drive and pump assemblies are completed and ready for mounting on the end cover of the main base, gaskets are fitted to the mounting flange of the drive assembly and to the distance piece located between the pump suction flange and the end cover. This distance piece is ground to suit each installation and must not be interchanged with those of other units.

When mounting the completed assembly on the end cover, the mechanism should be tested for freedom as the bolts are tightened. This can be done by inserting the hand through the inspection ports provided in the drive casing.

Lubricating oil is supplied to the drive assembly by a tube leading from the main lubricating oil header of the engine. This tube is connected to a passage in the casing which communicates with a circumferential groove machined in the outer diameter of the upper section of the vertical shaft bushing. From this groove drilled passages in the bushings, shafts and casing conduct the oil to the bearing surfaces.

All parts of this assembly may be inspected and the various clearances checked through the openings provided in the casing. If the drive must be disassembled for any reason, the following will serve as a guide at reassembly.

1. Fit the vertical gear shaft to the gear shaft bushing with a diametrical clearance of .003 in. and an end play of .008 in. (The latter clearance is obtained by scraping the end faces of the bushing).

2. The case-hardened collar is then to be fitted to the shaft, dowelled and secured in place by the lock washer and lock nut.

3. Install the gear shaft and bearing assembly in the casing and secure in place by means of the lock screw.

4. Install the horizontal drive shaft end bushing.

5. Scrape the horizontal drive shaft bearing until a .003 inch feeler can be inserted between the bearing and the shaft.

6. Fit the drive gear key in the keyway provided in the horizontal shaft.

7. Place the drive gear in the bearing and press the horizontal shaft in the gear until the latter is hard up against the boss.

8. Check the thrust of the horizontal shaft which should be a minimum of .0015 inch.

9. Fit the bearing flange tooth housing and secure same with the bolts provided.

10. Check the backlash of the gears which should be about .006 inch.

11. Remove the bearing and drive shaft as a unit from the housing and by means of the lock washer and lock nut provided for this purpose, secure the gear in place on the drive shaft.

12. Install the drive pin in its tapered and dowelled fit in the head of the drive shaft and secure by means of the drive pin nut.

13. Reinstall the completed drive shaft and bearing assembly in the casing and secure by means of the bolts provided. Lock the bolts by wiring them together with soft iron wire.

14. Check the assembly shafts for freedom.

15. Slip the spline coupling on the vertical shaft and pin same in place with cotter key.

16. With the pump cover flange gasket in place bolt the pump to the drive casing and check the shafts for freedom.

17. With the large drive casing flange gasket in place, position the spacer between the pump and cover and mount the assembly.

18. Check the shafts for freedom as the mounting flange bolts are taken up.

19. Install the lubricating oil lines and the inspection port covers, completing the assembly.

PRESSURE REGULATING VALVE

The lubricating oil pressure in the system is controlled by an adjustable spring loaded regulating valve set at 35 psi located in the discharge pipe from the radiators to the engine header. To adjust the pressure, remove the valve cap, loosen the lock nut and turn the adjusting screw in to increase the pressure or out to decrease the pressure. Fig. 5-5.

LUBRICATING OIL STRAINERS

Two .005 Cuno lubricating oil strainers are mounted in the forward end cover ahead of the lubricating oil header and are similar to those used in the fuel oil system, Fig. 1-6. When turning the handle, the foreign matter scraped off drops from the strainer and accumulates in the base end cover until cleaned out. Always turn the strainer handle clockwise. The strainers may easily be removed from the base end cover by simply removing the nuts on the bolting flange and withdrawing the entire element. Care should be exercised in removing the strainer unit to see that particles of dirt are not scraped from the outside of the unit and allowed to fall into the clean oil compartment.

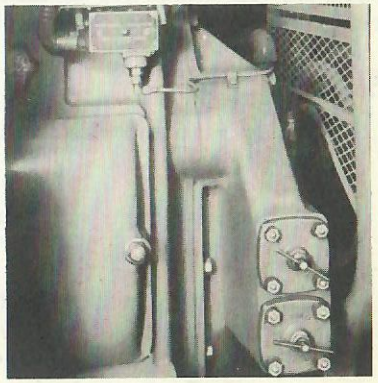


FIG. 1-6
LUBRICATING
OIL STRAINERS

The cleaning handle should be turned each day until experience dictates otherwise. This condition will vary considerably with the circumstances under which the engine is operated. This strainer should be removed often and the accumulation in the base end cover cleaned out; this will also be governed by experience. If, due to neglect, the cleaning handle refuses to turn readily, do not force it. The strainer should be removed and cleaned in some suitable solvent.

LUBRICATING OIL FILTER

Each engine lubricating oil system is fitted with a one or two unit waste-packed oil filter through which the oil is passed. These filters are of the cartridge type and are so located as to make the removal of the cartridge and replacement a comparatively easy matter. The road switcher has two of these filters in the radiator compartment and the standard 1000 HP switcher has one in the radiator compartment while the standard 660 HP has one filter located in the engine room.

These filters should be repacked often enough to keep the oil clean but at least once a month. A spare ready packed element will minimize delay.

Filter Removal

1. Remove top casting and filtering element from filter.
2. Remove wire ring and washer from the end of element.
3. The dirty waste and the center screen covered tube are to be removed. These can be slipped straight up off the inner center tube.
4. Remove the dirty waste from the screen covered tube being careful not to damage the copper screen.

Filter Packing

Replace screen covered tube in element and repack element with 7-1/2 pounds of long strand cotton waste. It should be packed evenly and firmly to eliminate voids through the filtering material. A blunt end stick can be used to pack the waste down firmly. It must be packed evenly around center tube so that it does not push the center tube over to one side. The packing should be checked frequently during packing by trying the upper steel washer on the center tube. While dismantled, check relief valve and spring.

Filter Installation

1. Replace top washer and retaining wire and insert element in filter housing.
2. Replace top casting and gasket. Check gasket to see that it is clean and is not broken. Tighten the four nuts on the top evenly. Check for leaks after engine is started.
3. Before reinstalling element be sure that the bypass valves in the filter itself are operative.

FILTER CHECK VALVE

Check for proper oil circulating through the filter by feeling the relative temperatures of the filter casing and the oil lines. A cold filter with engine operating would indicate oil is not circulating through the filter. In such a case check the setting of the check valve just ahead of the filter. This is set for 35 psi operating pressure.

LUBRICATING PROBLEMS

Dilution

Water — Discoloration of the lubricating oil to a gray brown color is evidence of water in the oil. Any thickening or emulsifying of the oil is more evidence of water.

Possible sources of water in the oil may be a cracked cylinder head, cracked cylinder liner, defective liner seal rings or a plugged water pump drain pipe which will cause the tray to fill up allowing water to go through the drive shaft bearing and thence into the gear casing.

Fuel Oil — The presence of fuel oil in the lubricating oil can be detected by a gradual rise in the lubricating oil level during operation, lowering of oil pressure or by a definite fuel oil odor in the lubricating oil.

Possible sources of fuel oil in the lubricating oil may be a leaky pipe connection in the fuel injection nozzle or a defective check valve in the fuel injection nozzle or a defective check valve in the fuel drain return pipe to the tank.

Excessive fuel dilution will thin the lubricating oil to such an extent that the lubricating oil pump can not maintain pressure high enough to prevent the low oil pressure switch from operating. Therefore, the engine will shut down due to the low lube oil pressure.

Low Lubricating Oil Pressure

1. Check oil level in engine.
2. Check for clogged Cuno filters and clean by rotating handles.
3. Check for leaks, broken pipes and worn bearings.
4. Valve in line to waste packed oil filter may be stuck.
5. Pressure regulating valve stuck or backed off.
6. Oil may be hot from improper manipulation of radiator shutters.
7. Check for dilution.
8. Defective lubricating oil pump or built-in relief valve.
9. Idling speed too low.
10. Oil stoppage in radiator core.

Excessive Oil Consumption

This may be caused by an oil leak; worn broken or stuck piston rings; broken, stuck or clogged oil control rings or an improper grade of oil.

Lubricating Oil Specifications

Use any recognized good grade of Diesel lubricating oil as manufactured by reputable oil companies providing it has the proper viscosity characteristics.

The oil must not be compounded with any animal or vegetable matter or any other substance that might be injurious to lead base bearings.

Please note that no attempt is made here to give any specifications which are a measure of quality and for that reason we recommend that the purchase of satisfactory lubricants be made from a reputable oil company whose standing is known to be high in the industry and one that has sufficient technical facilities to properly supervise its production as to quality and uniformity.

The following are the recommended viscosity characteristics for lubricating oil for the Diesel engine:

Viscosity

Max. SSU @ 100° F.	1300
SSU @ 210° F.	65-80
Flash Point, Min. °F.	390
Pour Point, Max. °F.	35
Carbon Residue, Max. %	.5
Water and Sediment	Trace

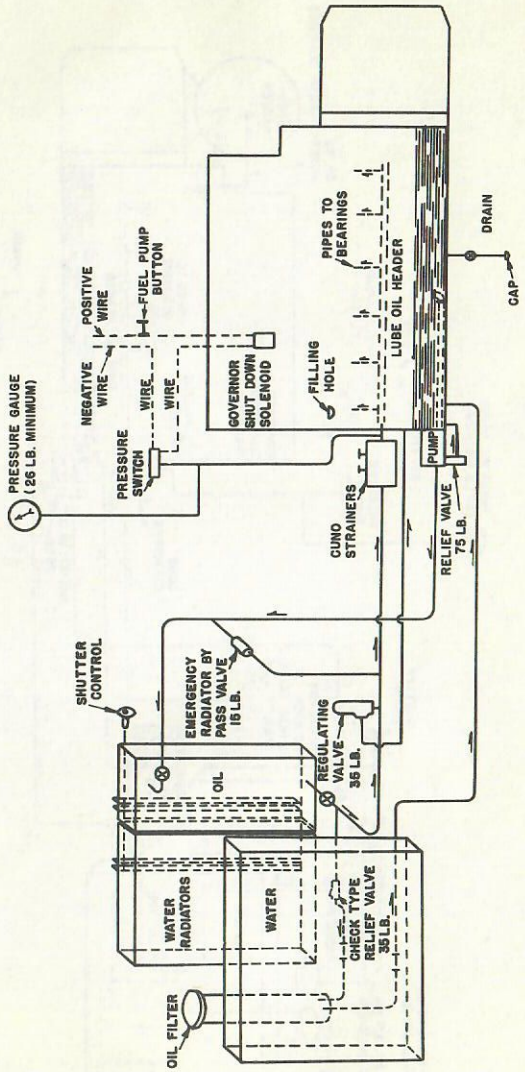


FIG. 2-6
LUBRICATING OIL SYSTEM
660 HP SWITCHER

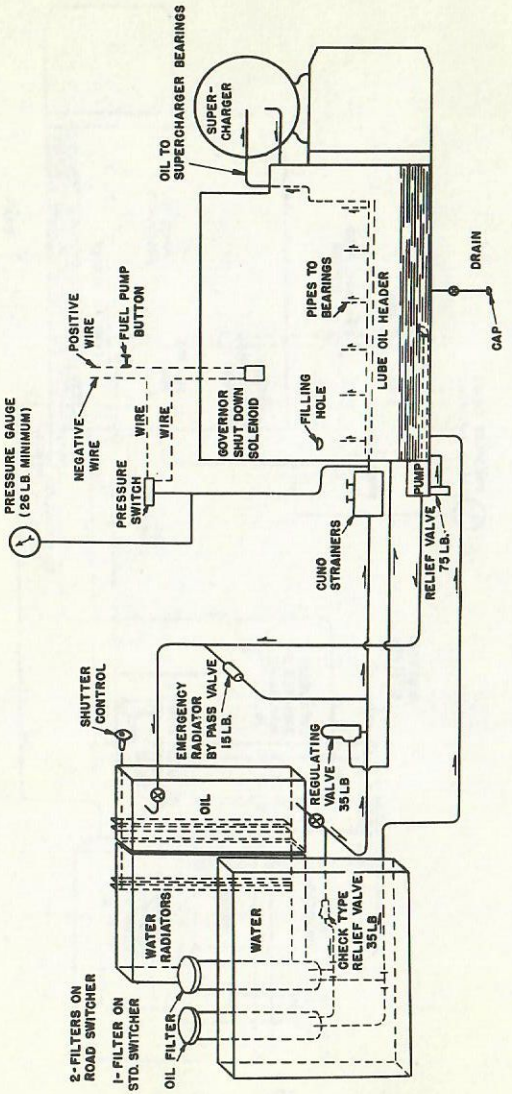


FIG. 3-6
LUBRICATING OIL SYSTEM
1000 HP SWITCHER AND ROAD SWITCHER

COOLING WATER SYSTEM

DESCRIPTION

The cooling water, circulated by a pump, flows into the cylinder block around the liners, up through passages into the cylinder heads and out the water elbows into the water outlet manifold. Water from the manifold flows to the radiators, cab heater and expansion tank. It is a closed system with the expansion tank vented to atmosphere through an overflow pipe.

FILLING THE SYSTEM

FIG. 1-7
FILLING CONNECTION

The system may be either filled under pressure by connecting to an air hose type connection, Fig. 1-7, under the left center of the locomotive or by gravity through a roof filling hole into the expansion tank.

When filling under pressure, close the turbocharge drain valve (1000 HP engine), open the fill-drain valve located of the floor at the left side front of the engine, open the cab heater valves and open the engine block drain valve, Fig. 2-7. Fill under a maximum pressure of 25 psi until gauge glass shows full or until water runs out of the vent pipe. Close the fill-drain valve, disconnect the hose and close the engine block drain valve.

In extreme cold weather, leave the engine block drain valve cracked open as the pipe from the block to the valve might freeze and crack.

7

WATER LEVEL

The water expansion tank is located at the highest point in the cooling water system and is equipped with a sight level glass, Fig. 3-7, and overflow pipe. Never operate the engine without water showing in the sight glass.

WATER TREATMENT

Water treatment compound must be used at all times to maintain the Diesel engine cooling system in proper condition and to prevent corrosion. Do not use a boiler water treatment compound or oil in the engine water. Where antifreeze compounds are used, special instructions will have to apply and materials shown herein should not be used. Treatment compounds or cleaners that will attack the rubber hose connections, cylinder head gaskets or that might corrode fitted joints must not be used.

It is recommended that the following quantities of either Dearborn 517 or Nalco 38, which are powder treatments,

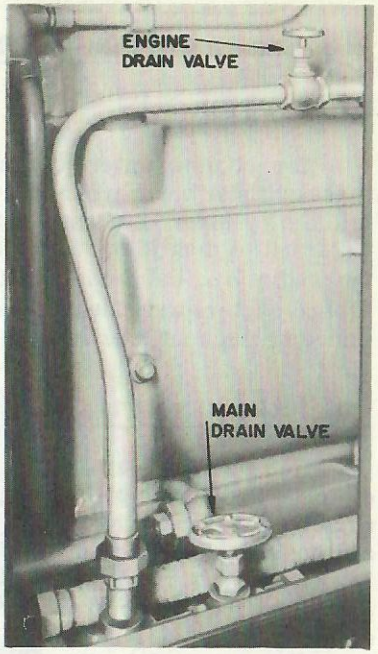


FIG. 2-7
FILL AND DRAIN VALVES

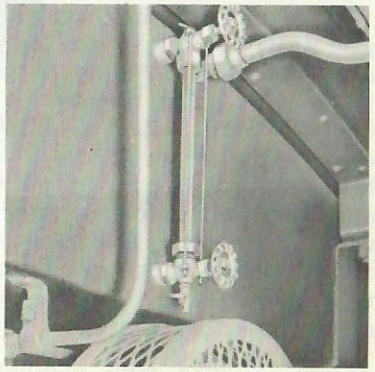


FIG. 3-7
SIGHT GLASS

be added to maintain ph value of 8.5 minimum and chromate concentration of 2000 parts per million minimum at all times.

Use 7-1/2 pounds of Dearborn 517 or Nalco 38 for each complete filling of the cooling system and 1/2 ounce for each gallon of water added thereafter.

Only clean water must be used in the cooling system. Examine engine interior at time of overhaul to determine whether or not correct treatment has been followed. Treatment compounds should not be allowed to come in contact with the body. When treatment is used, it is not necessary to flush the system except for unusual causes.

OIL IN WATER SYSTEM

In case oil is ever noticed in the water glass, which indicates oil in the water system, eliminate the source, flush the system, refill and add 10 pounds of tri-sodium phosphate. The engine should be operated with this solution in the system, for one day only, then drain and flush. Refill the system with fresh water and add the correct amount of water treatment.

DRAINING THE SYSTEM

Remove the dummy coupling on the air hose type filling pipe connection. Open the fill-drain valve, engine block valve, turbocharger drain valve (1000 HP engines) and the cab heater valves. By opening these valves, water will drain from the expansion tank, radiators, cab heater, turbocharger and all of the Diesel engine.

Open the vent valve on top of the cab heater to insure proper drainage of the cab heater.

WATER PUMP

The pump is of the centrifugal, single suction, closed impeller type, driven by a gear running off the fuel pump

drive gear. The impeller is bronze and the shaft is rustless steel. Water lubrication of the pump is automatic from the pressure system of the pump.

The clearance between the water pump shaft and bushing should not exceed .006. Excessive clearance may be detected by removing the suction head and prying the impeller end of the shaft up and down by hand. If excessive clearance is found, renew the pump.

A small amount of water should always drip from the water pump packing and run off through the pipe drain. Keep this drain pipe clean as lube oil dilution can be caused by the water level rising high enough to work through the drive shaft bearing and into the gear case. The water leaking by the packing serves to lubricate the shaft. The amount of leakage should be several drops a minute. If leakage is excessive, the packing nut should be tightened. It must not be tightened too much as without leakage the packing and shaft will wear excessively. Excessive leakage can be caused by a loose packing nut or worn shaft.

RADIATOR CORES

Radiator cores may be used for either oil or water on the 660 and 1000 HP switchers. On the road switcher the oil cores are the same as on the 660 and 1000 but the water cores are type AX98 and are so marked.

FREEZING WEATHER PRECAUTIONS.

The use of anti-freeze is not recommended because of the use of water treatment in the system and the fact that anti-freeze will not prevent the lubricating oil from congealing when the engine is shut down. Anti-freeze also attacks the rubber grommets and pipe thread sealers and lowers the boiling point of the water.

During layover periods in freezing weather, particular precaution should be taken that the engine cooling water is heated or drained. Steam from an external source can be admitted through the water filling connection, the steam valve opened to admit 4 - 5 pounds of steam. If water cannot be heated keep engine running; if engine cannot be run or water heated, drain radiator before the water becomes cold; drain engine and turbocharger.

Check the amount of water treatment in the water after heating the system with steam and add the necessary amount of treatment to replace the loss.

COOLING PROBLEMS

Water Leaks

Water leaks should not be permitted. In case an unusual amount of water is required, inspect:

1. All water piping.
2. Inspect the hoses.
3. Make sure drain valves are closed.
4. Inspect radiators for leaks.
5. Inspect around the cylinder heads, water manifold, etc. Blow off the block just below the head each month to maintain it clean for inspection.
6. An internal leak to the lubricating oil such as from the lower end of the liner will be indicated by drops of water on the base screens or on top of the cylinder heads. The engine must be shut down in case of water in the lubrication oil, the trouble corrected and oil changed.

High Engine Temperatures

For excessive or faulty temperature indication, note:

1. Water should not be permitted to boil.

2. If the engine has overheated from low water it should be allowed to idle and warm or hot water (150 degrees - not boiling) should be added slowly if available. If cold water is to be used, add it very slowly after the engine has cooled down to the extent that your hand can be held comfortably on the engine jacket.

3. Check water circulation and temperature by feeling various parts of the system.

4. The engine block drain valve should be closed when engine is running (leave valve cracked in cold weather) or high temperatures may result.

5. Check shutter position and operation. Shutters should be examined to insure blades open full and pins are not worn excessively.

6. Radiator fan drive should be operating. If fan is not operating due to belt failure, loose belts or other cause do not operate engine.

7. Engine water pump should always be in good working order. If examination of system indicates pump is not working or water not circulating, engine should not be operated.

8. Check hose on both intake and outlet pipes and equalizing hose connecting engine water outlet header to the expansion tank.

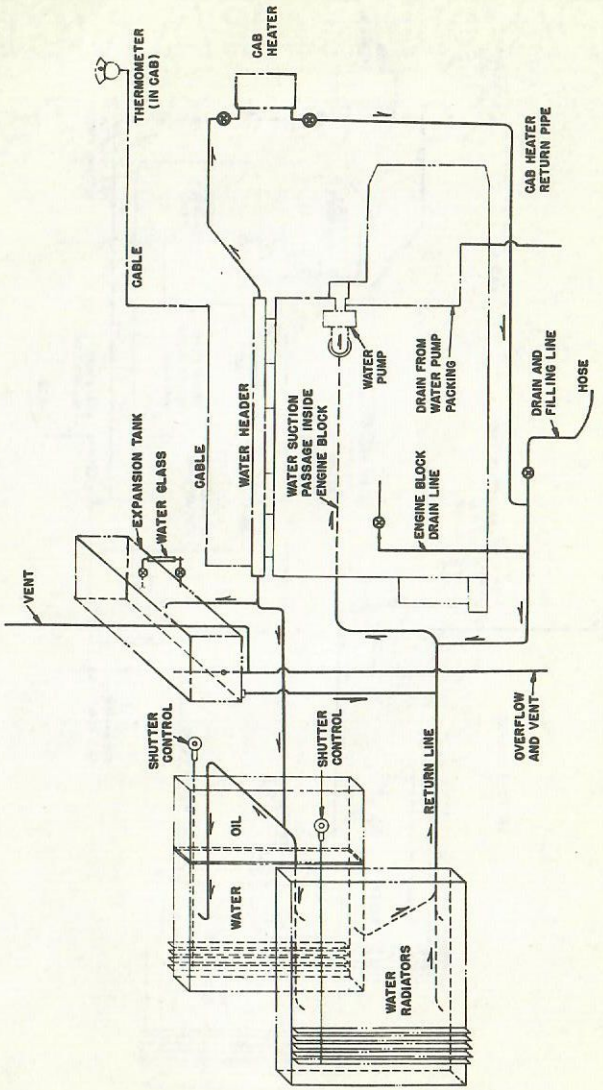


FIG. 4-7
COOLING WATER SYSTEM
660 HP SWITCHER

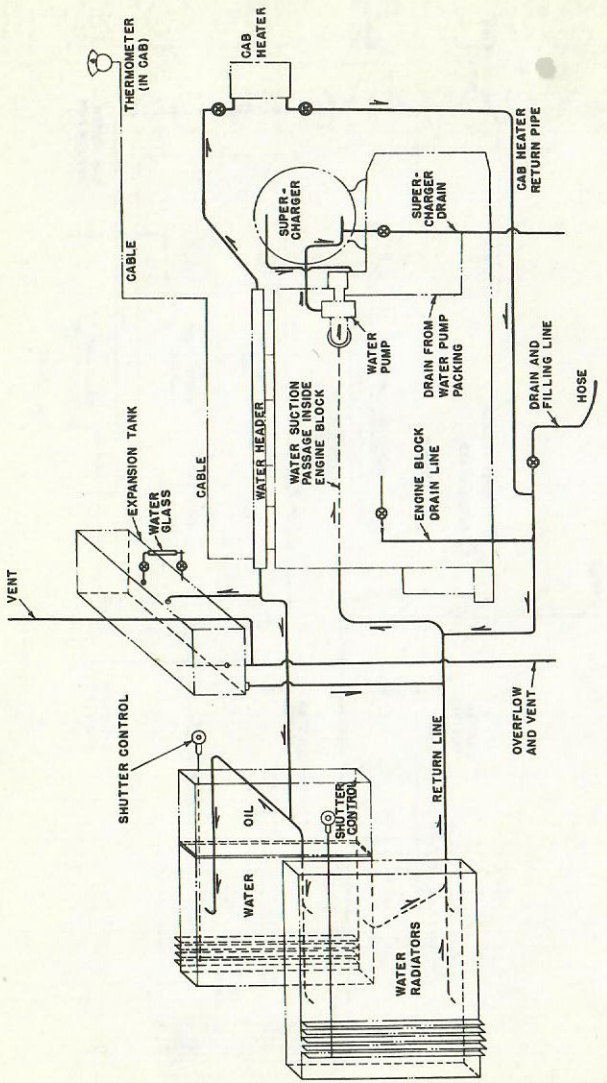


FIG. 5-7
COOLING WATER SYSTEM
1000 HP SWITCHER AND ROAD SWITCHER

AIR SYSTEM

AIR COMPRESSOR

Description

Each locomotive is equipped with a Westinghouse Type 3 CD, three cylinder air cooled, compound type air compressor, rated at 228 CFM at 740 RPM and 76 CFM at 275 RPM. It is driven from the stub shaft of the main generator through a flexible coupling.

Intake Strainers

The two air intake strainers, one for each of the low pressure cylinders, are of the "cartridge type" which permit removal of the strainer element without the necessity of dismounting or disconnecting from the air compressor. Air passing through the strainer unit enters the compressor intake.

The strainer element should be cleaned periodically. Dirt deposited on the metal wire mesh cover may be dislodged by jarring the strainer and by using dry compressed air. The blast of air should be directed along and not against the strainer unit. The strainer element should then be cleaned in an alkali-free hydrocarbon solvent and dried after which it is dipped and given a lubricating oil bath. After the oil has drained off, it is ready to be put back into service.

Intercooler

Since this compressor is of the compound type, it is fitted with an intercooler, through which the discharge air from each low pressure cylinder passes to the intake of the high pressure cylinder. The use of an intercooler reduces the temperature of the discharge air and improves the volumetric and power efficiency of the compressor. The intercooler is of the radiator type, em-

ploying finned copper tubing mounted between cast iron headers. The intercooler is divided in two halves, one for each of the low pressure cylinders. The low pressure discharge air enters the intercooler through a side header leading to the top or upper header where it is directed down through part of the tubes in the one-half of the intercooler and back up through the remaining tubes in that half. In this way the air from each low pressure cylinder is so directed through its half of the intercooler that, in passing to the high pressure cylinder, the air has traveled approximately twice the length of the intercooler tube. Suitable baffles are employed to insure that the air follows the path desired. After passing the tubes the air enters a common passage leading to the intercooler safety valves and to the inlet side of the high pressure cylinder. Two type E-1 safety valves are employed to protect the intercooler against excessive pressure. These safety valves are set to open at 60 psi.

About the only attention the intercooler should need is draining to insure removal of moisture. Drain the intercooler every time the main reservoirs are drained. A drain cock is located in the bottom header of each bank of intercooler tubes.

When handling the intercooler care should be exercised to avoid damage to the finned tubing and also to see that undue strains are not placed on the header assembly. The top header is one piece while the bottom header is in two pieces to accommodate expansion due to temperature change. The lower headers are tied together by means of a bottom tie strap and capscrews and upon its removal the intercooler may be lifted vertically. When handling, replace the strap to prevent distortion of the assembly.

Compressor Details

The compressor consists of two low pressure and one high pressure cylinders. The two low pressure cylinders are the ones at either side and can readily be

distinguished from the high pressure one because of their larger diameter. The three connecting rods are of forged steel and are identical They are applied to a common throw of the crankshaft. Each rod has its individual bearing on the shaft. Lubrication for the crankshaft end of the connecting rod is by pressure feed through the drilled crankshaft. The connecting rod is rifle drilled to the wrist pin which also is supplied with lubricant under pressure.

The cast iron pistons are fitted with four piston rings; two compression and one oil ring above the wrist pin and one oil ring below the wristpin. All piston rings should be applied so that the scraping edge is toward the crankcase.

Piston wrist pins are of the full floating type and are supported in the connecting rods by means of bronze bushings. The wrist pins are prevented from having excessive end movement by retaining rings which snap in a recess in the piston and thus prevent the wrist pins working out against the cylinder wall.

The main bearings are the radial ball type, one at each end of the crankshaft. They are lubricated by means of "throw-off" from the connecting rod bearings. An oil seal is provided at each end of the crankshaft to prevent oil leakage and also to guard against entrance of dirt.

Internal Oiling System

The oiling system is arranged so that oil under pressure is circulated by means of an oil pump. The oil pump is driven by an eccentric at one end of the crankshaft. This pump combines a piston and check valve operating in an oil pump body and is so arranged as to deliver the lubricating oil under pressure to drilled openings in the crankshaft.

The oil supplied to the pump is first filtered. The

filter consists of a housing incorporating a fine screen strainer of large area through which the oil is drawn on its way to the oil pump body. The screen strainer is held in place by a screen retainer which must be removed before the screen can be removed.

The oil gauge should show approximately 15 psi at 500 RPM and should still show pressure at idling speed.

An oil pressure relief valve, mounted in the crankshaft throw towards the intercooler, is provided to protect the oil pump and associated parts against excessive oil pressure.

Lubrication

Lubricating oil is carried in the base of the compressor which is equipped with a bayonet gauge, filler and drain connections, filter and breather. Twelve quarts of crankcase oil should be maintained in the compressor crankcase. For oil change periods and specifications refer to the Lubrication Schedule.

Oil Pump And Strainer

To dismantle the oil pump, it is first necessary to remove the main bearing end cover on the end of the compressor away from the intercooler. With the crankshaft rotated so that the oil pump plunger is in the vertical position, the entire oil pump plunger and body assembly may be removed by pulling it endwise along the compressor crankshaft.

To remove the oil pump strainer, take out the oil strainer body bolt and pull the strainer assembly out toward the intercooler.

In replacing the main bearing cover, care should be used to enter the end of the oil pump body properly in the cover, which supports it.

Connecting Rods And Pistons

The connecting rods are of the split type and are fitted with laminated shims for adjustment. The crankshaft end of the connecting rod contains the bearing metal which is poured into the rod. Access to the connecting rods and the interior of the compressor for inspection can be made through the side plates on either side of the compressor just below the low pressure cylinders. If, for any reason, it becomes necessary to remove the pistons or connecting rods, the low pressure pistons can be taken out without disturbing the cylinders. They come out through the top of the cylinders after removing the heads.

To remove a high pressure piston, it is necessary to remove the high pressure cylinder before the rod can be taken out. After removal of the cylinder, the piston is lifted out through the opening left by the removal of the cylinder.

Air Valves And Unloader Arrangement

There are two inlet valves and one exhaust valve for each of the low pressure cylinders and the high pressure cylinder. They are of the double washer type and all are located in the compressor head.

The inlet valves of the two low pressure and of the one high pressure cylinders are equipped with unloaders which are controlled by a governor. They are so arranged that when the compressor has restored the pressure in the reservoir system to the desired point, the compressor will unload and cease to deliver air to the main reservoirs.

The tapped opening in the cap nut of each of these unloader cylinders connects to a copper pipe header which leads to the compressor governor. When the compressor has reached the desired pressure in the reservoir, the governor admits main reservoir air through

this tapped opening in the cap nut onto the face of the unloader valve. This pressure immediately moves the unloader valve in towards the cylinder, carrying with it the intercooler pressure seal valve. This, in turn, acts through the unloader plunger which has as a part of the plunger, a head with four fingers or prongs on its lower side. These prongs extend through openings in the inlet valve seat. With the pressure admitted as described above, these fingers will push the inlet valves off the seat and the compressor is then unloaded, as no compression takes place as long as the inlet valves are thus held open. Complete movement of the unloader valve on which the main reservoir pressure first acted, results in its seating and preventing leakage of main reservoir air through the unloader assembly to the atmospheric vent.

When the pressure in the main reservoir has dropped to the point where it is desired to cause the compressor to operate, the governor assumes the "cut-in" position which vents main reservoir air from the face of the unloader valve. The return and unloader springs then move the unloader valve outward, carrying with it the unloader plunger and the four fingers which unseated the inlet valves. The inlet valves are seated then by the valve springs and the compressor resumes delivery of air to the main reservoir.

Discharge Valves

If for any reason it is desired to remove or inspect the discharge valves, it is only necessary to remove the cap nut and then back out the valve plug using a rectangular bar wrench 1/2" x 1/2" x 3' long which fits into rectangular slots on the face of the plug. A large monkey wrench will be necessary to turn the bar, or a "T" handle wrench with 1/2" x 1/2" head might be more suitable. After removal of the valve plug the complete discharge valve assembly can be lifted out, the seat, valves, springs and spring retainer being held together by a stud, castle nut and cotter pin.

Inlet Valves

The inlet valves are held in place by the unloader body and an inlet valve plug like that described for the discharge valve. To remove the inlet valve assembly, first remove the unloader body and lift out the unloader valve assembly. Back out the inlet valve plug, using the bar wrench as described for the discharge valve, which will free the inlet valve assembly and permit its removal. The valve assembly — seat, valves, springs and spring retainer — are held together by a stud, castle nut and cotter.

Replacing Inlet And Discharge Valve Assemblies

When replacing inlet and discharge valve assemblies in the cylinder head it is important that the copper gasket between the head and valve seat is in good condition. Generally, it is better policy to replace this gasket with a new one when reassembling. The same gasket is used for all inlet and discharge valve assemblies. It is also important to make absolutely certain that valve assemblies are replaced with the castle nut side pointing outward, i.e., away from the compressor piston. In some instances it might be possible to turn an assembly over and should this be done, serious damage to the compressor might result if operated under this condition.

The valve and valve springs of all inlet and discharge valve assemblies are completely interchangeable. The inlet and discharge valve seats are not interchangeable. All inlet valve assemblies have the same valve seat; all discharge valve assemblies have the same valve seat.

Crankcase Breather

The compressor crankcase is vented by means of a breather with cap. It has a quantity of copper gimp supported between suitable screens retained in place by means of a snap ring. The breather is also fitted with a check valve so arranged that any pressure in the crank-

case will be relieved to atmosphere, but any tendency for air to flow from the outside of the compressor into the crankcase is prevented. This check valve is felt-sealed for quiet operation.

ORIFICE TEST

Use a 17/64" diameter orifice with square edges and bored through a plate 1/16" thick. The orifice and gauge should be placed in the reservoir farthest from the compressor. With the compressor running at 550 RPM the following table shows the condemning limit pressures at various altitudes.

Elevation (ft.)								
0	1000	2000	3000	4000	5000	6000	7000	8000
Condemning Limit (psi)								
102	98	94	90	86	82	78	75	71

AIR COMPRESSOR GOVERNOR

Type - NS16

This governor is of the pneumatic double "safety valve" type and consists of two distinct portions; the operating portion and the pipe bracket. Pipe connections to the compressor and to the main reservoir are provided for in the pipe bracket so that the operating portion may be removed for repairs or replacement without breaking any pipe joints.

The operating portion casting is marked HP and LP. The adjusting screw in the HP section is used to regulate the point of air compressor cut-out or unloading point while the adjusting screw in the LP section is used to regulate the point of air compressor cut-in or loading

point. Therefore, it is necessary to set two pressures when adjusting the governor, the High pressure, where the governor unloads the compressor and the Low pressure, where the governor loads the compressor.

To adjust governor pressures, loosen both lock nuts where the adjusting stems protrude from the top of the governor and screw cutout regulating stem (HP side) down until the desired cutting-out point is reached. A main reservoir air pressure gauge is located near the governor for use when making pressure adjustments. At the same time screw down cut-in regulating stem (LP side) to as nearly the same tension as can be judged under ordinary observation. If when the cutting-out point is reached the range is not as desired, screw the cut-in regulating stem down to raise the cutting-in point or to decrease the range and back it off to lower the cutting-in point or to increase the range.

This governor needs very little attention after being properly adjusted except to be cleaned and oiled periodically. When cleaning and oiling the governor, a few drops of good oil should be placed on the surface passed over by the cutting-in and cutting-out valves. See also that the exhaust opening is free from dirt or gum and the strainer is clean.

Type S16

If locomotives are equipped with air compressor synchronization, Type S16 governor is used. This type of governor, in addition to the operating portion and pipe bracket, also has an air operated switch which controls current to a magnet valve in each locomotive unit. The magnet valve controls the flow of main reservoir pressure to the air compressor unloader valves in its unit. By means of this control, all air compressors are either loaded or unloaded simultaneously.

Governor maintenance instructions and pressure adjustments are made the same as on the NS16 governor.

The switch has self-contained contact fingers and bases encased in molded insulation and can be readily removed as units without special tools. The finger adjustment is permanent and accomplished without use of screws. An efficient pneumatic blow-out when the governor cuts out, in combination with the peculiar shape of the contacts, insures that the opening arc is definitely lengthened, cooled and then effectively extinguished.

TESTING SAFETY VALVE

In order to test a main reservoir safety valve it is necessary to keep the air compressor loaded above the governor high pressure setting. In order to accomplish this, close the governor air supply cutoff valve. This prevents main reservoir pressure reaching the air compressor unloader valves and thereby keeps the compressor loaded.

AIR SYSTEM

Air from the compressor passes through cooling pipe, then through a safety valve set at 10 psi higher than the main reservoir pressure. The air then enters the No. 1 main reservoir under the frame, right side, then through more cooling pipe into the No. 2 main reservoir, left side. Air supply lines are connected to the No. 2 main reservoir which furnish air for the control air system, air compressor governor, sanders, air brake system, bell, horn and window wipers.

CONTROL AIR SYSTEM

Air pressure is used to operate the reverser, series and series-parallel contactors. The system includes a cutout cock, strainer and check valve, reducing valve, air gauge and reservoir. The air gauge is mounted on the gauge panel at the engineer's position while the rest of the equipment is located below the underframe on the fireman's side of the locomotive.

Air pressure from the No. 2 main reservoir is reduced to 70 psi by the reducing valve and stored in the control air reservoir.

If the gauge should indicate pressure other than 70 psi, the trouble will probably be found in the reducing valve. Close the cutout cock and open the drain valve in the control air reservoir to drain the system of air before removing the reducing valve.

If high pressure is indicated no serious difficulties should be experienced before the trouble is corrected. However, low pressure will cause the electro-pneumatic contactors and reverser to become inactive with the result that the locomotive will not move.

DRAINING AIR SYSTEM

The air system should be drained daily or after each trip to prevent moisture from reaching the air brake and control air systems.

Drain the following:

1. Air compressor intercooler — both sides.
2. Main air reservoirs.
3. Control air reservoir.

SANDING

Standard switching locomotives have air operated sanders for the front wheels of the front truck and back of the back wheels, rear truck.

Forward sanding is obtained by moving the engineer's sander valve to its forward position and reverse sanding is obtained by moving the valve to its back position.

Actuating air from the engineer's valve controls the flow of main reservoir air through the sander control valves to the sand traps.

With multiple-unit control forward and reverse sanding is controlled from the engineer's foot pedal type sander valve through the reverser. Electrical connections from the forward or reverse position of the reverser control the operation of magnet valves.

Actuating air from these magnet valves control the flow of main reservoir air through the sander control valves to the forward or reverse sand traps.

To increase the amount of sand flow turn the nozzle adjusting nut, located at the sand trap, clockwise and to decrease the sand flow, turn the nozzle adjusting nut counterclockwise.

AIR BRAKE SCHEDULE

For operation and maintenance information on the brake equipment used on the switching locomotives, refer to Westinghouse or New York Air Brake instruction pamphlet covering 14 EL equipment. This is similar to 6 ET equipment used on steam locomotives. A control reservoir is added which supplies air to the electro-pneumatic reverser and motor contactors S, SP1 and SP2.

AIR PROBLEMS

Loss of Air Pressure

1. Compressor governor may be stuck — try tapping it.
2. Control air should be 70 pounds. Check control air reducing valve, cutout cock and strainer under locomotive frame.

Poorly Maintained Main Reservoir Pressure

1. Compressor valve leaking — causes low pressure.
2. Compressor governor sticking — causes either high or low pressure.
3. Broken unloader pipe — causes high pressure.
4. Sticky unloader valves — causes low or high pressure.
5. Internal failure of compressor — causes low pressure.
6. Closed cutout cock in governor pipe — causes high pressure.

Air Pressure Does Not Build Up

1. See that main reservoir drain valves and brake pipe angle cocks are closed.
2. Compressor governor may be stuck. Try tapping it.
3. Faulty compressor.
4. Compressor drive coupling may be faulty.

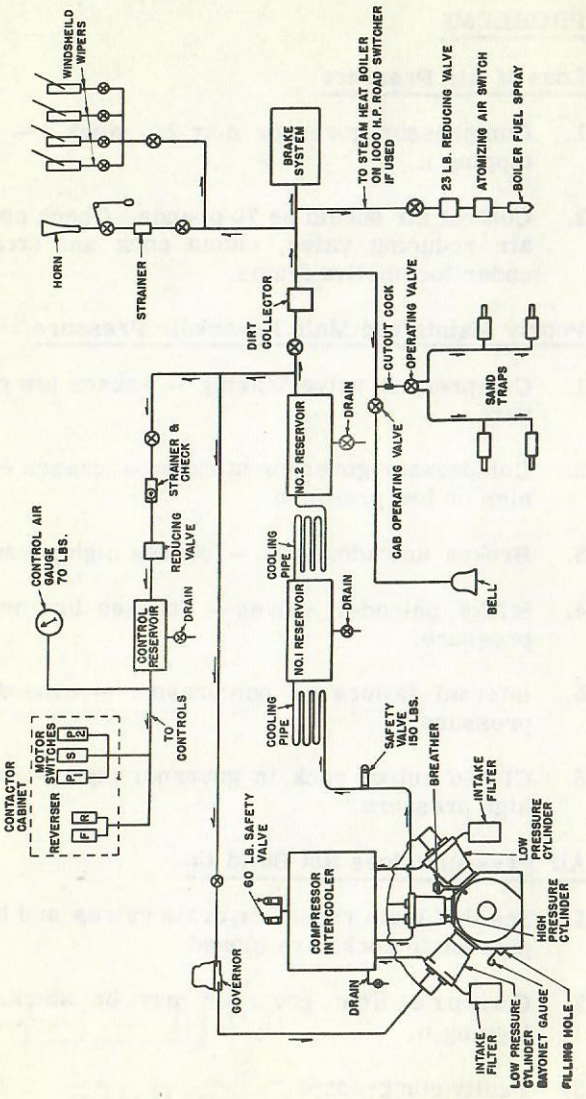


FIG. 1-8
SCHEMATIC AIR SYSTEM

CHASSIS

BATTERY

The locomotive storage battery is the heart of the electrical system. Its primary duties are engine cranking and furnishing current for control and lighting circuits.

The battery is made up of 32 cells, four in each of eight trays. Four trays are carried in the battery box on each side of the locomotive. The life of the battery will be prolonged by regular inspections, recording conditions and taking immediate corrective steps as necessary.

When a new battery is received the electrolyte level in all cells should be checked. If the level is more than 1/8" below the bottom of the filling tubes, add electrolyte of the same specific gravity and check to see if cells are leaking.

There are two means of checking the operation of the battery. These are by observing the specific gravity of the electrolyte and by noting the water level. If the voltage regulator is adjusted to maintain these two characteristics within the prescribed limits, the life of the battery will be prolonged and optimum operation will be obtained.

HYDROMETER READINGS - SPECIFIC GRAVITY

The specific gravity of the electrolyte in the battery as measured with a hydrometer, will rise on charge and lower on discharge. The hydrometer reading of the fully charged battery at 77° temperature should be 1.275. A change of 30° in battery temperature will change the hydrometer reading 0.010 (10 points). Readings taken at low temperatures will be lower than those taken at high temperatures with the same electrolyte.

When taking hydrometer readings be sure to hold the syringe vertically so that the hydrometer will float freely. Do not take readings immediately after adding water to a cell. Allow a day in service for the water to mix with the electrolyte. Do not use the same cell all the time to take readings. Each month change to another cell. Be careful not to spill any of the electrolyte, returning all of the electrolyte to the cell from which it was removed.

BATTERY INSPECTION

Every day the specific gravity of the electrolyte of one or two cells should be tested with a hydrometer and their electrolyte level checked. Use one cell in each battery section for check but change to another cell in each section each month.

The hydrometer should read within the limits of a fully charged battery and not less than 35 points below or 1.240.

It is normal for the battery to require the addition of water and the level in the battery cells must be kept above the top of the plates, but at least 1/8" below the bottom of the filling tube. However, there is a definite amount of water which should be consumed over a period of time by a battery being properly charged. The addition of water should be as indicated below:

Water Additions Per Month Per Locomotive Battery

Maximum - 10 Quarts

Minimum - 5 1/4 Quarts

If the battery is using excessive water it is receiving too great a charge and vice versa.

BATTERY REGULATION

Since current from the battery furnishes standby lighting control current and starts the engine using the main generator as a starting motor, the current used must be restored by the auxiliary generator.

The auxiliary generator, with its voltage controlled by a voltage regulator, maintains an approximately constant voltage across the battery throughout the range of Diesel engine speed. The fully charged no load or open circuit battery voltage is 64. The auxiliary generator voltage is approximately 75 as measured in the contactor compartment across terminals A+ and A- at the base of the voltage regulator.

To adjust the voltage of the battery, it is necessary to use an open scale voltmeter placed in the charging circuit across terminals A+ and A- on the voltage regulator. When checking the regulator setting, the coils must be hot and adjustment is made by using the high and low speed adjusting rheostats on the regulator; these should be adjusted alternately until the voltage is the same for both speeds. Never adjust the voltage more than 1/2 to 1 volt until the locomotive has operated in its normal service for a day and the results checked. Normally the auxiliary generator voltage will be about 75 volts but will vary slightly as the necessary adjustments are made to maintain the batteries properly charged under different operating conditions.

BATTERY - GENERAL RULES

1. Cleanliness is important. Prevent collection of dirt and oil on the top of the battery. With the battery switch open wash off with ammonia or baking soda solution (1 pound of soda to a gallon of water) and rinse with water. Blow out battery compartments and space between trays and wash the entire compartment and top of the battery with a hose under moderate pressure quarterly; then blow out the surplus water with an air hose.

2. Do not lay metallic objects on top of the battery.

3. Keep all connections in the battery circuit tightly bolted and clean.

4. Add only distilled or approved water. Addition of electrolyte is unnecessary unless some is spilled and acid or special compounds should never be added.

5. When taking hydrometer readings be sure to hold the syringe vertically so hydrometer will float freely and note the corresponding electrolyte temperature. Do not take readings immediately after water has been added. Each day take readings in a different cell.

6. If one particular cell varies considerably from the others either in respect to specific gravity or water consumption, investigate and correct the cause. Give equalizing charge.

7. Keep a daily record of battery inspections.

BELT DRIVES

The following are the belt drives on the locomotive:

Traction Motor Blowers

The traction motor blowers are located at each end of the locomotive. These should be inspected occasionally during operation to be sure that cooling air is going to the traction motors. Belt slippage will mean that less air will go to the motors and the motors will overheat. Each blower supplies air to two motors.

Auxiliary Generator

The slippage of belts between the generator and exciter-auxiliary generator will result in the loss of power.

Radiator Fan

The slippage of belts between the engine and radiator fan will cause improper engine cooling.

General

Any excessive belt slap or noise at the pulleys should be corrected.

Belts that are excessively tight may cause a bearing failure. The points to check are:

1. Coupling, pulley, belts and bearings in the auxiliary generator drive.

2. Pulleys and belts in the drive of both traction motor blowers.

3. Pulleys, coupling, bearings, belts and right angle gear box of the radiator fan drive.

BELT INSTALLATION

Inasmuch as V belts have contact surfaces on the side walls, the high tension required with flat belts will not apply.

If possible a complete set of new matched belts should always be installed and the remaining old belts removed. If sufficient number of good second hand belts have accumulated it may be possible to match same up and utilize them for future installations.

These should not be used on a drive where it is expected to keep same in service for a long length of time or where application is difficult, as naturally the life of these used belts will be less than new belts.

When applying new belts to any drive, the tension device should be released so that the belts can be applied freely over the pulleys. If the belts are forced over the pulleys a ply-break may occur resulting in damage to the belts.

After a set of belts have been applied, the drive should be run for approximately three-quarters of an hour before checking the tension. This will allow the belts to become well seated and equalized on both sides of the pulleys before checking for tension.

After the belts have been broken in on the drive, the tension may be checked roughly by depressing the belt in the center (this is halfway between the two pulleys). This amount will vary somewhat on account of the variation in center distances and of course the amount of depression is dependent on the center distances of the drive but, ordinarily this should be from 1/2 inch to 1 inch. The force exerted should be the normal pressure possible to exert with one finger without straining.

If too much tension is applied, trouble will be experienced on the bearings of the drive, with resultant short belt and pulley life. If the belts are applied too loosely, the belts will slip, thereby decreasing their life.

Belt dressings are not required and should never be used. Belts should be kept clean and free from oil. Belts not in use should be stored in a cool dark place as excessive heat deteriorates the belts. Do not store on a damp floor or where water or steam may damage the belts. When necessary to replenish stock make sure that belts previously in stock are used before using the newly acquired belts.

When applying new belts a continuous type V belt should be used. When applying a new set of belts, care should be taken to have the belts a matched set. Connector type belts can be used in an emergency. These should be replaced as soon as possible.

Belts should never ride the bottom of the grooves.

PULLEYS

Pulley Groove Wear (Steel or Cast Iron)

1. Pulley groove wear has been found to have a great bearing on belt life. Pulleys should be regrooved or resurfaced at reasonable intervals. Some railroads resurface their cast pulleys by spraying the grooves with a mixture of high carbon steel. The grooves are then remachined to size and polished.

2. When resurfacing is not done but where pulleys are to be machine turned, the amount of wear and the extent of turning should be done in accordance with the following table. The amount of wear and turning shown is for ONE side of the groove only.

First condemnation point at	.030 inch wear
First turning to	.040 inch
Second condemnation point at	.070 inch wear
Second turning to	.080 inch
Third condemnation point at	.120 inch wear

If wall thickness is less than 1/8 inch after third turning, the pulley is to be scrapped.

Pulley Replacement

Pulleys should be inspected to insure their being tight on the shaft at all times. The pulleys have a taper fit (except idler pulley) and in each case during repair or replacement the following rules should be observed.

The pulley should be pulled up tight, should have a good fit over the shaft surface and the key should be carefully fitted so that the pulley does not rest upon it.

Pulley Alignment

When applying new pulleys or making adjustments, make sure the running pulleys are in alignment to insure straight belt operation.

AIR COMPRESSOR DRIVE FLEXIBLE COUPLINGS

Disc Type Coupling (Thomas)

Locomotives equipped with this type should be inspected monthly for correct condition of all coupling parts. The bolts should be tightened after the first few days of service and then should remain tight without further attention. The hubs should be secure on the shafts at all times. The coupling should be dismantled at major overhauls and worn parts replaced.

Oil Lubricated Type Coupling (Fast)

Alignment

In applying a new or checking the old coupling:

1. The sleeve (A), Fig. 1-9, should be entered over shaft end before the hub (B) is forced on and keyed. The key must fit on its sides for the entire length of the hub. It must not bear on top or bottom.

2. The hubs of this coupling must be separated in accordance with the dimension found stamped on the alignment faces of the hubs. The No. 4 requires 1-1/2 inch.

3. The shafts should then be lined up by using a straight edge and inside calipers (D) on alignment faces on hubs as shown.

4. The flanges of the sleeve should be cleaned and gaskets examined to insure oil seal and then bolted solidly together.

5. Adjustment for alignment is made by positioning the compressor. The same care in alignment should be used as if a solid coupling were used.

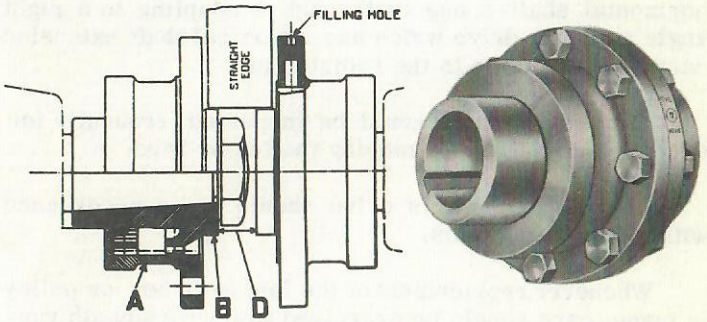


FIG. 1-9
OIL LUBRICATED TYPE OF COUPLING

Maintenance

After the locomotive has been in service for a few days all flexible coupling bolts should be tightened. Thereafter the coupling should be inspected once a month to be sure that everything is in good condition.

This coupling requires lubrication. Through one of the two holes provided in the flange of the coupling put in Crater Compound No. 1 or equivalent. Be sure to replace the plugs tightly. It is advisable to check the coupling lubrication quarterly by separating the bolted flanges to see that the teeth are properly lubricated.

The coupling should be dismantled at major overhauls and worn parts replaced.

RADIATOR FAN DRIVE

This drive is equipped with idler pulleys for adjustment and to insure smooth running. The driving pulley is fastened directly to the main crankshaft at the No. 1 cylinder end of the engine.

The driven pulley is fastened to a horizontal shaft located over head in the radiator structure housing. The horizontal shaft connects through a coupling to a right angle gear box drive which has a vertical shaft extension carrying the power to the radiator fan.

The gear drive should be inspected frequently for excessive back lash by moving the fan by hand.

Lubrication of this drive should be in accordance with recommendations.

Whenever replacement of the fan, gear box or pulley is made, care should be exercised to insure smooth running or balance of the fan, good alignment of the shafts at the coupling and of the upper pulley with the lower one.

The right angle gear box is built and assembled as a unit. Proper alignment must be obtained if it is ever renewed.

Radiator Fan Drive Alignment

The gear box unit and the two bearings for the drive shaft are mounted on a frame with bolts. The bolt holes in the frame are oversize to allow for shifting of the parts.

Two ten inch dummy flanges with four .750 inch holes drilled about 4 inches from the center of the flange are used for aligning the drive shaft with the gear unit. They are mounted on the drive shaft and the gear box shaft.

Four dowels which fit into the holes in the flanges are used in aligning the shafts. The clearance between the dowels and the holes in the flanges is .002 inch maximum.

The flanges are spaced about two inches apart by four steel bushings. These bushings are all the same length. They are held in place by the dowels. The bushings are also drilled .750 inch.

The bearings and/or gear box unit are shifted and shimmed until the shafts are in alignment.

The tolerance is plus or minus .002 inch.

After the alignment is complete all parts are drilled, taper reamed and the taper pins driven in place.

Dummy flanges are then removed and the flexible coupling is assembled to the drive shaft and gear unit.

Radiator Fan Mounting

Remove all burrs and nicks on the gear box unit shaft and the bore and bore keyway in the fan hub.

Start the fan on the gear box unit shaft and by "rocking" the complete assembly back and forth the fan is "jarred" on the shaft.

The holding nut is then put on and locked with a cotter pin.

Radiator Fan Removal

The fan may be removed from the drive shaft by using the fan puller tool after the holding nut has been removed.

ENGINE AIR FILTER

The 660 HP engine has a panel filter built as part of the air manifold while the 1000 HP engine has panel type filters mounted on a filter box which is bolted to the compressor end of the turbocharger.

Filters should be serviced every 200 or 300 hours

in switching service under average conditions. Servicing consists of washing, rinsing, oiling and draining.

Filter Washing

Washing is best accomplished by immersing the filter in an agitated hot cleaning solution for 2 to 5 minutes. Agitation can be accomplished with perforated steam pipes. Cleaning compound could be Oakite 24 or equal with approximately 4 ounces of cleaning compound used per gallon of water.

Filter Rinsing

The process of rinsing is merely to protect the filter from effects of the caustic solution and may be accomplished by immersing in a tank of fresh water or spraying fresh water through a nozzle.

Filter Oiling

The only way to be sure of having all the filter media coated with oil is to dip the filter into a tank of oil for approximately 6 seconds until bubbles start to rise to the surface. In order to prevent emulsification of the rinse water remaining on the filter with the oil it is recommended that the oil be kept at a temperature of approximately 110 to 120 degrees F. with suitable arrangements for draining off collected water at periodic intervals. An oil of from SAE 40 to SAE 60 viscosity is recommended for temperatures above freezing and SAE 10 to SAE 20 below freezing.

Filter Draining

Filters should be drained from 16 to 20 hours at a temperature equal to or 10 degrees above the temperature at which the filters are to operate.

In no case are they to be drained at temperatures above 125 degrees F. Ovens in which the temperature is maintained constant are suitable for this purpose.

VENTILATING AIR SYSTEM

Radiator Cooling Air

Air is drawn through the radiators which are located on the sides of the engine hood and blown out through the hood roof by a radiator fan. The fan is driven by a right angle gear box, V-belts and pulleys driven from the end of the lubricating oil pump drive shaft. The flow of air is controlled by shutters of which there are three sets. A set is located on each side over the radiator sections and one set is on the hood roof over the radiator fan.

Maximum air flow and cooling is obtained with all shutters wide open and minimum air flow and cooling with all shutters tightly closed.

The radiator sections on the left side are all for water. On the right side 2/3 of the sections are for water and 1/3 for oil. If when maintaining water temperatures in cold weather it is necessary to open the radiator shutters, it is better to open the left side shutters in preference to the right side shutters.

Traction Motor Blower

Air flow is necessary to keep the traction motors cool. This air is drawn from the engine room by blowers, which are belt driven off either end of the main crankshaft. Air is forced down through the center castings and truck bolster to the two traction motors on the truck. One blower is provided for each truck.

The blower drives should be inspected periodically to make sure that the blowers are operating and delivering air to the traction motors. Broken belts or a failed drive should be corrected at once.

TRUCKS — 660 and 1000 HP STANDARD SWITCHERS

The standard power trucks are of the four-wheel, center bearing type. The bolster casting is designed to form the nose mounting for the two traction motors on each truck and also the attachment of the brake cylinders which are located outside of the track line. The ends of the longitudinal side extensions of the bolster are encased in a three-sided shoe which bears against a channel attached to the side frame adjacent to the truck boxes thus keeping the truck square in horizontal alignment without interfering with vertical flexibility. The bolster rests on the side frames through a parallel spring suspension system consisting of one long semi-elliptic and two triple coil springs on each side. This springing arrangement has been found to produce the easiest possible riding characteristics since the coils absorb all shocks not great enough to deflect the semi-elliptic spring, while the semi-elliptic spring, in turn, acts as a dampener of vibrations in the coils.

This construction provides positive equalization at all times without distortion of any truck members, regardless of any uneven track condition. The absence of end frames increases the accessibility to the motors. One size of journal is used for both the 660 and 1000 HP switching locomotives having a journal bearing and wedge similar to AAR construction for lateral flexibility. The lateral thrust of the axles is absorbed by axle end thrust bearings carried in the combined cellar and end cover of the journal box.

Clasp brakes are standard equipment using long shoes to reduce wear. All brake adjustments are placed on the outside of the truck and inspections can be made and brake shoes replaced without having to go over a pit.

Center Plate

Both the body and truck center plates have vertical

and horizontal wear liners of hardened steel. An oil cup located under the side sill feeds oil through a pipe to the wearing surfaces. If the pipe is clogged or obstructed in any manner, excessive centerplate wear will result. Check frequently to be sure that oil is feeding through the pipe. If the vertical liner in the truck bolster centerplate assembly should break loose and rotate in the casing, it would cut off the oil supply.

The top of the truck center plate is provided with a felt seal and plate to guard against the entrance of dirt.

Side Bearings

Conventional type side bearings are used. The vertical clearance between the frame and these bearings when new is 1/4 inch each side of locomotive If the clearance is reduced it indicates that the center plate is wearing. If clearance is reduced to 1/8 inch on each side, renewal of the center plate wear liners should be considered.

Brake Travel

The brake cylinder piston travel should be set in accordance with railroad standards. A short piston travel will give a very satisfactory and quick responding brake.

Brake Lever Pin and Clevis Wear

Brake lever pins, bushings and clevises should be maintained in good condition. After these parts and the brake shoes have worn a certain amount, brake travel can no longer be taken up with the turnbuckle adjustment. If this occurs, the brake pull rod may be shortened by moving the pin to the second hole in the rod. If it is necessary to move this pin to the third hole to maintain piston travel, then all brake pins and clevises should be renewed at first opportunity.

Pedestal Shoes

The pedestal shoes on the ends of the bolster extensions have individual oil cavities formed on top. Oil is led through holes and grooves to the three surfaces in contact with the channels attached to the side frames. If lubrication is properly maintained, shoes will wear very little. The clearance between the shoe and side frame on all three sides of each shoe when new is 1/6 inch. If wear progresses to 1/8 inch on a side, liners should be welded to the side frame to restore the original clearance. If shoe wear progresses another 1/8 inch the pedestal shoe may have to be renewed. If the shoes should wear on a taper, they should be squared.

Lateral Motion

Lateral motion of the axles is taken by thrust bearings placed at the axle end. This bearing is oil fed through a wick which lies in the journal box cellar.

The new clearance between the thrust bearings and the axle ends when new is 1/8 inch at each end. This clearance combined with the clearance at the pedestal shoes gives a total truck lateral of 3/8 inch.

If the lateral becomes excessive, check to see that the pedestal bearing clearances are not excessive as shown in a previous paragraph. The wear on the axle end thrust bearings themselves will be very slight. However, they should be replaced if they wear to the point where the axle ends cut the journal brasses.

Traction Motor Suspension

Each traction motor is suspended by two bearings on its axle; and on a suspension lug, spring nest and wear plate at its nose.

The suspension bearings have both radial and lateral clearance. The initial radial clearance is 1/32 inch.

The initial lateral clearance between the bearing collar and the wheel or gear hub is 1/32 inch at a side which gives a total lateral of 1/16 inch to the traction motor. When renewing wheels care must be taken to maintain the lateral at this figure.

The wear plate at the nose suspension should be checked and maintained.

There are two 0.007 inch shims between the axle cap and frame of the motor. Removal of one of these shims will increase the clamping fit or draw on the bearing shell. Removal of these shims or their omission when replacing a motor may cause excessive clamping action on the bearing shell and result in its failure in service. Shims should be applied whenever new bearings or motors are installed.

Wheel Turning and Limitations

When turning or replacing, the wheels on any one axle should be within 1/2 tape. Wheels should be taped and held to A.A.R. standard.

On any one truck the recommended allowable difference in wheel circumference is 2 tapes.

The clearances between traction motors and top of rail with a 40 inch wheel when new are:

Under Motor	-	6-1/2 inches
Under Gear Case	-	4-1/4 inches

Wheels should be checked periodically for tread wear in accordance with railroad standards.

In case tread wear is excessive the following should be checked:

1. Alignment of the brake shoe hangers.
2. Gage the wheels.
3. Check to see that truck parts are not excessively worn as previously described.
4. Make sure that brake piston travel is being properly adjusted.

   If the locomotive is switching continually on a curve in one direction, it is advisable to periodically turn the locomotive around. If this cannot be done it is possible to turn the trucks end for end, if minor changes in the piping to the brake cylinders are made.

Removing Truck on 660 and 1000 HP Standard Switchers

The usual method of removing a truck is as follows:

1. Remove steps and footboards.
2. Disconnect all traction motor leads, brake cylinder connections and disconnect safety hooks.
3. Lift up both ends of locomotive at jacking pads to prevent breaking of center casting.
4. Roll out truck.

   The specially made jacking pad extensions should be used to jack up the locomotive. If the extensions are not used, the truck brake cylinder will not clear the jack and it will be impossible to roll the truck out.

After the truck is removed the following should be done:

1. Inspect the traction motors, inspect gear and pinion, clean gear case and repack suspension bearings.
2. Inspect and repair all truck wearing parts in accordance with previous paragraphs. An overhead crane or hoist of some kind is essential when doing work on these trucks.

FLANGE OILERS

Where flange oilers are used to reduce wheel wear, the following points should be watched.

1. Use the proper grade of lubricant.
2. Adjust flow of lubricant so that it is even on all wheels.
3. Be sure that too much oil is not being fed. Excessive feed may cause oil to get in the traction motors, poor braking, etc.
4. Take care to see that the feed stick is adjusted to ride on the correct part of the flange.

REMOVING TRACTION MOTORS

Dropping Wheels

Where a drop pit and wheel lathe are continuously available it may take less time to turn wheels if they are dropped one pair at a time than it would take if the entire truck was dismantled. To drop a pair of wheels proceed as follows:

1. Spot locomotive with wheels to be dropped about one inch off the center of the ram.

2. Lace up the traction motor to the underframe. Eyes are provided in the top of the motor frame and holes are provided in the bottom of the locomotive frame so that studs may be screwed into the holes. Also lace the traction motor so as to prevent it falling away from its nose suspension on the bolster. This may be done by passing a chain through the eyes in the motor frame and around the center casting.

3. Remove journal box cellars and pedestal binders. The binders are held in place by taper bolts which should be driven out.

4. Remove brake rigging where necessary.

5. Remove traction motor suspension bearing caps, brasses and gear case.

6. Jack up or provide support for the truck side frames.

7. Jack up one end of locomotive enough to pick up weight of traction motor.

8. Dropping the pedestal binders has also dropped spacer plates inside the boxes so that there is now room to roll the wheels away from the traction motor and unmesh the axle gear from the motor pinion. The axle may then be dropped.

LOCKED TRACTION MOTOR ARMATURE

In the event that a traction motor armature should ever lock while the locomotive is in service either drag the locomotive to the round house, sliding the wheels or remove the gear casing and burn off the teeth of the pinion gear where they mesh with the axle gear.

HOT TRACTION MOTOR AXLE BEARING

This is evidenced by smoke or odor. In switching service, notify the maintainer. In road service, remove the waste, discard charred portions and repack the bearings being sure the waste is against the axle. Add plenty of oil pouring some directly on the waste. After running several miles, inspect the bearing.

TRACTION MOTOR AXLE BEARINGS

These motors are shipped new with two 0.007 inch shims between the axle cap and frame. When the locomotive has traveled 10,000 miles, these shims should be removed.

Inspection

The bearings should be inspected at regular intervals to check the oil depth. (1-3/4 inch minimum, 3-1/2 inch maximum, measured on slant).

1. Clean off all dirt around the waste pocket and oil well covers.

2. Lift covers and examine waste. Change any glazed waste.

3. Make sure that waste is packed tightly against window and the bearing lining flanges are being properly lubricated.

4. Using a suction pump, take a sample of oil from the bottom of the oil chamber to check for water. If water is found it should all be withdrawn from the bearings and bearings repacked with fresh waste.

5. Bearings should be repacked after 25,000 to 30,000 miles of service or every 6 months, whichever comes first.

Packing Bearings

Empty and clean out waste chamber, Fig. 2-9. Be careful that no dirt drops into it. These axle caps are fitted with a spring waste pusher. A thin wood or fibre wedge should be inserted between the pusher and the axle to keep the spring compressed while the bearing is packed. If the wedge is inserted in the center of the waste opening, the waste can be packed on both sides of it. The wedges should be removed after packing.

Long fibre wool waste should be used as packing. All the waste to be used should be thoroughly saturated with warm oil for 24 hours and allowed to drain for 12 hours. (Temperature approximately 85 degrees F.)

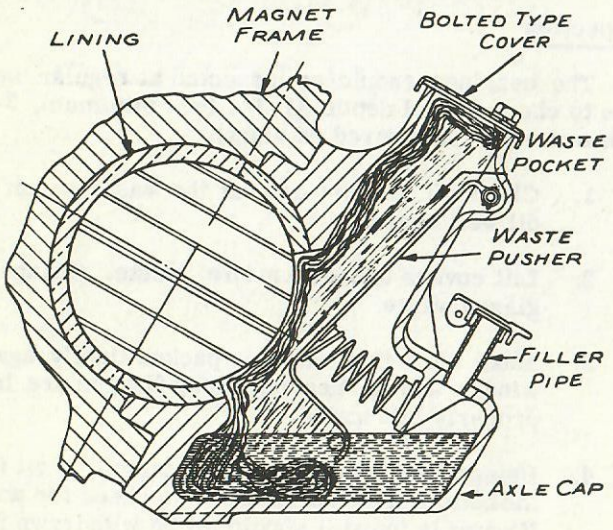


FIG. 2-9
AXLE CAP

1. Make several wicks or skeins by twisting the long strands together once or twice.

2. Place the wicks in the window side of the waste chamber so that they extend from the bottom to about 6 inches above the top and force them firmly against the shaft by packing more waste behind them.

3. Fold the top of the wicks back over the packing and fill the remaining space with a wad of waste well saturated with oil to exclude dirt.

4. Replace cover on waste chamber.

Filling The Bearing

1. Use a good grade of electric car oil. Unless the climate is very uniform throughout the year two grades of oil are required, one for summer and a lighted grade for winter.

2. Open the oil well cover and gauge the depth of the oil by inserting a clean rod or stick into the auxiliary oil well.

3. If the bearing is not sufficiently full, pour oil into the auxiliary oil well until the proper depth of oil is reached (3-1/2 inch maximum measured on slant).

4. Close oil well cover.

TRUCKS - 1000 HP ROAD SWITCHER

Before an axle and wheel assembly, with or without traction motor, or a complete truck can be removed from beneath a locomotive it is necessary to relieve the truck or trucks of the chassis weight. The jacking and lifting diagram shows the locations at which the locomotive may be supported either by jacks, a lifting rig used in conjunction with an overhead crane, or by stationary body supports frequently included with drop table installations. Tables on the jacking and lifting diagram show approximate loads involved. The following precautions should be observed: wood blocking should be used between chassis support points and lifting devices and lifts should be uniform on both sides of the locomotive to prevent unnecessary strain on super structure. The locomotive should not be lifted more at one end than at the other until the body center castings have become disengaged from the truck center plates.

Wheel and Axle Removal

To remove a wheel and axle assembly without removing the truck it is necessary to use a drop table. Support the chassis weight and block under the equalizers. Remove the pedestal tie bars, bottom brake pull rods, motor nose suspension spring unit, axle suspension bearing caps and gear case. Support the motor from the underframe by turn-buckles shackled into lifting eyes cast into the motor frame. Pull the motor toward the center of the truck approximately two inches to disengage the pinion from the axle gear and lower the wheel and axle assembly.

To remove a wheel and axle assembly with the traction motor attached it is necessary to use a drop table. Support the chassis weight and block under the equalizers. Remove the pedestal tie bars, bottom brake pull rods and motor nose suspension spring unit. Disconnect the traction motor leads and air duct. Block between motor and table and lower the assembly.

Removing Trucks on 1000 HP Road Switcher

To remove an entire truck, disconnect safety hooks, traction motor air ducts, air brake piping and traction motor leads. The lift required will be lessened if blocking is provided between journal box and pedestal tie bar so that equalizer coil springs cannot raise the frame.

A truck may then be removed by three different procedures:

If a drop table is used, the chassis should be supported either by stationary body supports bridging the table or by means of a lifting rig which requires an overhead crane.

Trucks may be removed laterally after raising the chassis sufficiently to disengage the center castings from truck center plates and to provide proper clearance above the trucks. Use either a lifting rig or jacks.

Trucks may be removed longitudinally along the track after raising chassis sufficiently to clear draft gear housing and pilot. Required lift will be lessened if pilot, handrails, steps, etc. are removed.

Refer to jacking and lifting diagram for details of lifts and loads involved.

Removing Coil Springs on 1000 HP Road Switcher Four Wheel Truck

Remove pedestal tie bars. Jack up truck frame until equalizers drop sufficiently to free coil springs. Remove coil springs.

Removing Elliptic Springs on 1000 HP Road Switcher Four Wheel Truck

1. Remove safety strap above bolster. Jack up locomotive about 2" more than enough to take load off truck.

2. Jack up spring plank close to hanger just enough to take weight of plank and springs off hanger.

3. Push swing hanger until it touches equalizer and lower one end of spring plank.

4. Unseat spring and move out over equalizer as far as possible.

5. Jack up truck frame until spring may be removed out the side.

Traction Motor Blower Alignment

Loosen the six hold-down bolts beneath the blower and also the bolts under the pillow block at the sheave end of the assembly before adjusting the jack screws to tighten the belts. Loosen the link belt flange coupling bolts occasionally and check the coupling deflection to insure proper alignment.

INSPECTION AND LUBRICATION

The following inspection and lubrication instructions supersede all lubrication charts and any other instructions pertaining to maintenance inspection periods with the exception of Bulletin TI-10.

Maintenance work is facilitated by work sheets listing the items requiring periodic inspection, with periods between inspections most conveniently arranged for the operating conditions of the particular locomotive.

The periods selected are representative of average results obtained in service and can be used as a guide in preparing work sheets for any particular operation.

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Periodic lubrication of all points should be carefully followed. Complete data are given in the Lubrication Schedule.

The Interstate Commerce Commission "Laws, Rules and Instructions for Inspection and Testing of Locomotives Other Than Steam" should be strictly adhered to along with work listed in this bulletin where mandatory. ICC inspection forms should be followed and prepared as required.

THE WORK LISTED UNDER EACH INSPECTION AND LUBRICATION PERIOD IS TO BE REPEATED WHEN THAT PERIOD INTERVAL RECURS.

MAINTENANCE INSPECTION PERIODS

660 HP AND 1000 HP SWITCHER LOCOMOTIVES

MECHANICAL - Daily

1. Air brake equipment test and inspection (ICC).
   a. Check air compressor pressures and governor.
   b. Check brake cylinder piston travel; equalize.
   c. Drain condensation from main and control air reservoirs and air compressor intercooler.
   d. Inspect brake shoes and renew as necessary.
   e. Test functioning of brakes.
2. Check operation of traction motor blowers.
3. Check locomotive supplies and equipment, fusees, torpedoes, flagging equipment, spare bulbs and fuses.
4. Check work report, also locomotive for defects (ICC).
5. Cooling water system.
   a. Add water if necessary together with treatment to bring the sight glass to 3/4 level.
   b. Check system for leaks.
   c. Inspect water level sight glass.
   d. Test water for proper treatment.
6. Examine engine air filters to determine whether cleaning and oiling is necessary.
7. Fuel oil system.
   a. Inspect tank gauge.
   b. Inspect tank and piping for leaks (ICC).
   c. Refuel.
8. Inspect belts on all belt driven auxiliaries.
9. Maintain all fire extinguishers in proper operating condition.
10. Note all gauges for correct operating pressures and temperatures.
11. Test operation of bell, horn and window wipers.
12. Test operation of radiator fan and shutters.
13. Test sanders and refill boxes as necessary.

LUBRICATION - Daily

Refer to lubrication schedule.

ELECTRICAL - Daily

1. Check operation of cab heater.
2. Check specific gravity of battery pilot cell. Add water to all cells, if necessary.
3. Make external inspection of all electrical rotating machinery for unusual noise, heat or odor while engine is running.
4. Make visual inspection in electrical compartment.
5. Test front and back headlights, cab and engine room lights.

MECHANICAL - Monthly

1. Repeat work listed under "Daily".
2. Adjust air and exhaust valves for .016 clearance. Check adjusting screw lock nuts for tightness.
3. Blow out radiators with dry compressed air.
4. Check engine speeds - 275 RPM Idle - 740 RPM full throttle.
5. Check all piping for leaks.
6. Check for broken air and exhaust valve springs and auxiliary air rocker spring.
7. Check for broken nozzle studs and loose stud nuts.
8. Check fuel injection pump rack linkage for freedom of movement.
9. Check fuel injection pump timing.
10. Check fuel oil lines at nozzles for leaks with the engine running.
11. Check fuel booster pump and coupling for alignment and tightness.
12. Check handbrake operation.
13. Check lubricating oil for acidity and viscosity.
14. Check oil and water radiators and connections.
15. Check operation of emergency fuel cutoff valve from the various knob positions.
16. Check engine overspeed safety device by tripping manually.

17. Check setting of low lubricating oil pressure switch.
18. Check water pump packing leakage (10 drops per minute maximum).
19. Clean air compressor air intake filters.
20. Clean locomotive and eliminate any fire hazard.
21. Clean or change fuel oil secondary filter.
22. Clean water expansion tank sight glass if necessary.
23. Drain, clean and repack duplex fuel suction filter (6 oz. of waste in each bowl).
24. Drain sediment and condensation from fuel oil filter tank mounted on engine block.
25. Drain sediment and condensation from fuel oil tank.
26. Inspect air compressor and radiator fan drive shaft flexible coupling, bolts and parts.
27. Inspect lower portion of cylinder liners.
28. Inspect radiator shutters and cooling fan mechanism.
29. Inspect traction motor blowers, radiator fan and drives.
30. Inspect trucks, brake rigging, wheels, springs, handrails, couplers, draft gears, steps, cab doors and uncoupling devices.
31. Inspect valve lever mechanism. Note operation and lubrication with engine running.
32. Make all ICC tests required.
33. Remove and clean engine air filters and oil with SAE 40 oil when outside temperature is above 10°F and SAE 20 oil below 10°F.
34. Remove crankcase covers and inspect pipe connections, connecting rod and main bearing nuts, bolts, and cotter pins. Look for signs of loose bearing metal on base screens and side walls.
35. Renew or repack lubricating oil filters and also at each oil change. (Use 7-1/2 lbs. of long strand cotton waste or sock type.)
36. Test and adjust belt tension.

ELECTRICAL - Monthly

1. Repeat work listed under "Daily".
2. Blow out the electrical compartment, all generators and motors with dry compressed air using low pressure and large volume.

3. Check current limit relay action and lamp.
4. Check equipment in electrical compartment for loose connections.
5. Check high and low voltage systems for grounds.
6. Check operation of auxiliary generator voltage regulator, adjust while hot at specified voltage at both high and low engine speeds.
7. Check operation of governor solenoid.
8. Check traction motor leads and connectors for looseness.
9. Check wheel slip relay buzzer action.
10. Clean and inspect contactors, relays and interlocks. (Sliding contacts to be lubricated).
11. Clean and inspect throttle switches.
12. Clean and inspect reverser, control fingers and segments.
13. Inspect brushes and commutator on fuel pump motor, traction motors, generators and cab heater motor.
14. Make complete contactor sequence test, observing contactor and relay operation.
15. Test all fuses and lights.
16. Wash out battery boxes; tighten and grease terminals.

LUBRICATION - Monthly

Refer to lubrication schedule.

MECHANICAL - Quarterly

1. Repeat work listed under "Monthly".
2. Apply orifice test to air compressor (ICC).
3. Clean air compressor breather filter.
4. Clean air compressor lubricating oil base strainer at oil change.
5. Clean control air filter.
6. Clean Cuno lubricating oil strainer; also clean at oil change.
7. Clean fuel oil filter tank mounted on cylinder block.
8. Drain and flush cooling water system.
9. Drain and flush Woodward governor.

10. Test air compressor intercooler safety valves for 60 lbs. setting.
11. Test air gauges (ICC).
12. Test main air reservoir safety valves.
13. Wash base and clean screens at lubricating oil change.

LUBRICATION - Quarterly

Refer to lubrication schedule.

MECHANICAL - Semi-Annually

1. Repeat work listed under "Quarterly".
2. Break connection at restricted fitting on lubricating oil line at outboard bearing on fuel oil pump drive shaft and clean.
3. Clean and test air brake equipment (ICC).
4. Remove, clean and inspect air compressor valves.

LUBRICATION - Semi-Annually

Refer to lubrication schedule.

MECHANICAL - Annually

1. Repeat work listed under "Semi-Annually".
2. Check calibration of temperature and pressure gauges.
3. Check crankshaft deflection.
4. Examine auxiliary generator and exciter drive shaft bearings.
5. Examine condition and check wear of auxiliary drive pulleys.
6. Examine traction motor blower drive shaft bearings.
7. Hydrostatic and hammer test main air reservoirs.
8. Inspect flexible couplings at air compressor and at radiator fan for worn parts.
9. Inspect main bearings, No. 4, No. 7 and one intermediate.
10. Inspect traction motor air ducts, side bearings, center castings, wheels for ICC defects, gears and pinions, motor suspension bearings, etc. when trucks are removed.
11. Remove and clean oil and water radiator cores and headers.
12. Remove and dismantle lubricating oil pump and drive for inspection.
13. Remove and dismantle water pump. Inspect and repair.
14. Remove and inspect one piston and cylinder liner to determine the general condition of cylinder heads, valves, liner wear, piston, rings and ring grooves, rods, pins, bearings and cylinder block. Check compression seal on cylinder head with a surface plate. Clean carbon and grind valves. Change piston rings and check ring groove wear at least once every two years.
15. Remove, clean and test fuel injection nozzles.
16. Remove, dismantle and clean turbocharger. Inspect and repair.
17. Remove, dismantle, clean and adjust Woodward governor.
18. Remove fuel injection pumps and test for output.
19. Surface inspect engine parts removed and magnaflux where possible.
20. Take up slack in throttle and governor linkage, installing new pins and bushings as necessary.
21. Thoroughly clean and inspect locomotive frame, deck plates, etc. (ICC).

ELECTRICAL - Annually

1. Repeat work listed under "Semi-Annually".
2. Apply insulation dielectric test (ICC).
3. Check calibration of ammeter (ICC).
4. Examine, clean and repaint all exposed wiring.
5. Measure traction motor axle bearing clearance and end play.
6. Remove and clean battery; repaint battery leads; recondition terminals; test by cycling or by standard railroad methods.

7. The following items should be inspected and repaired if necessary, to assure another year of operation.

Auxiliary Generator
Cab Heater Motor
Controller
Electro-Pneumatic Contactors
Exciter
Fuel Pump Motor
Magnet Valves
Magnetic Contactors
Radiator Fan Gear Box
Relays
Reverser
Traction Generator
Traction Motor and Gears

LUBRICATION - Annually

Refer to lubrication schedule.

MAINTENANCE INSPECTION PERIODS

1000 HP ROAD SWITCHER LOCOMOTIVES

MECHANICAL - Daily or Trip

1. Air brake equipment test and inspection (ICC).
   a. Check air compressor pressures and governor.
   b. Check piston travel; equalize.
   c. Drain condensation from main and control air reservoir and air compressor intercooler (daily).
   d. Inspect brake shoes and renew as necessary.
   e. Test functioning of brakes.
2. Check operation of traction motor blowers.
3. Check locomotive supplies and equipment, fusees, torpedoes, flagging equipment, spare bulbs and fuses.
4. Check work report, also locomotive for defects (ICC).
5. Cooling water system.
   a. Add water if necessary together with treatment to bring to 3/4 level in sight glass.
   b. Check system for leaks.
   c. Inspect water level sight glass.
   d. Test water for proper treatment.
6. Examine engine air filters to determine whether cleaning and oiling is necessary.
7. Fuel oil system.
   a. Inspect tank gauge.
   b. Inspect tanks and piping for leaks (ICC).
   c. Refuel.
8. Inspect belts on all belt driven auxiliaries.
9. Maintain all fire extinguishers in proper operating condition.
10. Note all gauges for correct operating pressures and temperatures.
11. Remove crankcase covers and inspect pipe connections, connecting rod and main bearing nuts, bolts and cotter pins. Look for signs of loose bearing metal on base screens and side walls.
12. Test operation of bell, horn and window wipers.

13. Test operation of radiator fan and shutters.
14. Test sanders and refill boxes as necessary.

ELECTRICAL - Daily or Trip

1. Check operation of cab heater.
2. Make external inspection of all electrical rotating machinery for unusual noise, heat or odor while engine is running.
3. Make visual inspection in electrical compartment.
4. Read specific gravity of gravity pilot cell. Add water to all cells, if necessary.
5. Test front and back headlights, cab and engine room lights.

LUBRICATION - Daily or Trip

Refer to lubrication schedule.

MECHANICAL - Monthly

1. Repeat work listed under "Daily or Trip".
2. Adjust air and exhaust valves for .016 clearance. Check adjusting screw lock nuts for tightness.
3. Blow out radiators with dry compressed air.
4. Check engine speeds - 275 RPM Idle - 740 RPM full throttle.
5. Check all piping for leaks.
6. Check for broken air and exhaust valve springs and auxiliary air rocker spring.
7. Check for broken nozzle studs and loose stud nuts.
8. Check fuel injection pump rack linkage for freedom of movement.
9. Check fuel injection pump timing.
10. Check fuel oil lines at nozzles for leaks with the engine running.
11. Check fuel booster pump and coupling for alignment and tightness.
12. Check handbrake operation.
13. Check lubricating oil for acidity and viscosity.
14. Check oil and water radiators and connections.

15. Check operation of emergency fuel cutoff valve from the various knob positions.
16. Check engine overspeed safety device by tripping manually.
17. Check setting of low lubricating oil pressure switch.
18. Check water pump packing leakage (10 drops per minute maximum).
19. Clean air compressor air intake filters.
20. Clean locomotive and eliminate any fire hazard.
21. Clean or change fuel oil secondary filter.
22. Clean water expansion tank sight glass if necessary.
23. Drain, clean and repack duplex fuel suction filter (1 lb. of waste in each bowl).
24. Drain sediment and condensation from fuel oil filter tank mounted on engine block.
25. Drain sediment and condensation from fuel oil tank.
26. Inspect air compressor and radiator fan drive shaft flexible coupling, bolts and parts.
27. Inspect lower portion of cylinder liners.
28. Inspect radiator shutters and cooling fan mechanism.
29. Inspect traction motor blowers, radiator fan and drives.
30. Inspect trucks, brake rigging, wheels, springs, handrails, couplers, draft gears, steps, cab doors and uncoupling devices.
31. Inspect valve lever mechanism. Note operation and lubrication with engine running.
32. Make all ICC tests required.
33. Remove and clean engine air filters and oil with SAE 40 oil when outside temperature is above 10° F and SAE 20 oil below 10° F.
34. Remove, clean and test fuel injection nozzles.
35. Renew or repack lubricating oil filters and also at each oil change. (Use 7-1/2 lbs. of long strand cotton waste or sock type.)
36. Test and adjust belt tension.

ELECTRICAL - Monthly

1. Repeat work listed under "Daily or Trip".
2. Blow out the electrical compartment, all generators

and motors with dry compressed air using low pressure and large volume.
3. Check current limit relay action and lamp.
4. Check equipment in electrical compartment for loose connections.
5. Check high and low voltage systems for grounds.
6. Check operation of auxiliary generator voltage regulator, adjust while hot at specified voltage at both high and low engine speeds.
7. Check operation of governor solenoid.
8. Check traction motor leads and connectors for looseness.
9. Check wheel slip relay buzzer action.
10. Clean and inspect contactors, relays and interlocks (sliding contacts to be lubricated).
11. Clean and inspect throttle switches.
12. Clean and inspect reverser, control fingers and segments.
13. Inspect brushes and commutator on fuel pump motor, traction motors, generators and cab heater motor.
14. Make complete contactor sequence test, observing contactor and relay operation.
15. Test all fuses and lights.
16. Wash out battery boxes, tighten and grease terminals.

LUBRICATION - Monthly

Refer to lubrication schedule.

MECHANICAL - Quarterly

1. Repeat work listed under "Monthly".
2. Apply orifice test to air compressor. (ICC)
3. Clean air compressor breather filter.
4. Clean air compressor lubricating oil base strainer at oil change.
5. Clean control air filter.
6. Clean Cuno lubricating oil strainer, also clean at oil change.
7. Clean fuel oil filter tank mounted on engine block.
8. Drain and flush cooling water system.

9. Drain and flush Woodward governor
10. Remove fuel injection pumps and test for output.
11. Test air gauges (ICC).
12. Test main air reservoir safety valves.
13. Wash base and clean screens at lubricating oil change.

LUBRICATION - Quarterly

Refer to lubrication schedule.

MECHANICAL - Semi-Annually

1. Repeat work listed under "Quarterly".
2. Break connection at restricted fitting on lubricating oil line at outboard bearing on fuel oil pump drive shaft and clean.
3. Clean and test air brake equipment (ICC).
4. Remove and dismantle water pump. Inspect and repair.
5. Remove and inspect main and connecting rod bearings.
6. Remove, clean and inspect air compressor valves.
7. Remove, dismantle and clean the turbocharger. Inspect and repair.

LUBRICATION - Semi-Annually

Refer to lubrication schedule.

MECHANICAL - Annually

1. Repeat work listed under "Semi-Annually".
2. Check calibration of temperature and pressure gauges.
3. Check crankshaft deflection.
4. Examine auxiliary generator and exciter drive shaft bearings.

5. Examine condition and check wear of auxiliary drive pulleys.
6. Examine traction motor blower drive shaft bearings.
7. Hydrostatic and hammer test main air reservoirs.
8. Inspect flexible couplings at air compressor and at radiator fan for worn parts.
9. Inspect pistons, piston pins, rings and check ring groove wear.
10. Inspect traction motor air ducts, side bearings, center castings, wheels for ICC defects, gears and pinions, motor suspension bearings, etc. when trucks are removed.
11. Remove and clean oil and water radiator cores and headers.
12. Remove and dismantle lubricating oil pump and drive for inspection.
13. Remove cylinder heads, grind valves and check compression seal with a surface plate.
14. Remove cylinder liners for inspection and renew seals. Turn liner one quarter turn when reapplying.
15. Remove, dismantle, clean and adjust Woodward governor.
16. Surface inspect engine parts removed and magnaflux where possible.
17. Take up slack in throttle and governor linkage, installing new pins and bushings as necessary.
18. Thoroughly clean and inspect locomotive frame, deck plates, etc. (ICC).

ELECTRICAL - Annually

1. Repeat work listed under "Semi-Annually".
2. Apply insulation dielectric test (ICC).
3. Check calibration of ammeter (ICC).
4. Examine, clean and repaint all exposed wiring.
5. Measure traction motor axle bearing clearance and end play.
6. Remove and clean battery; repaint battery leads; recondition terminals; test by cycling or by standard railroad methods.

7. The following items should be inspected and repaired, if necessary to assure another year of operation:

Auxiliary Generator
Cab Heater Motor
Controller
Electro-Pneumatic Contactors
Exciter
Fuel Pump Motor
Magnet Valves
Magnetic Contactors
Radiator Fan Gear Box
Relays
Reverser
Traction Generator
Traction Motor and Gears

LUBRICATION - Annually

Refer to lubrication schedule.

MAINTENANCE INSPECTION PERIODS
STEAM GENERATORS

VAPOR-CLARKSON TYPE
OK-4630 and OK-4616
DRK-4530 and DRK-4516

Daily or Trip

1. Clean the strainer in the water treatment tank. Fill the tank with water before replacing the cover. Make certain the cover is seated properly and clamped down tightly.

2. Clean the strainers in the water line. On the OK-4630 clean the strainer in the water manifold. There is no strainer on the OK-4616 that corresponds to this one. On the DRK-4530 and DRK-4516 clean the screen of the water strainer.

3. Close the return water outlet valve to shut off the pressure. Then clean the screen in the strainer between the separator and the steam trap. These strainers in the return water line are the "Y" type on the DRK and the square type on the OK.

4. Turn the handle on the fuel oil filter several times.

5. Check the oil level in the water pump crankcase. Add additional oil if necessary. Excessive loss of oil indicates that the pump should be replaced. There is an oil level stick on the 1600 pound units for this purpose, but the 3000 pound units have a petcock. If oil runs when opened, the oil level is high enough.

6. Empty the drip pan on the 1600 pound unit water pump.

7. If the unit is equipped with an injector water treater, turn the treatment filter handle several times. Check the amount of treatment in the tank. Note that a normal amount of treatment has been used.

8. Remove the peep sight glasses and clean them. While the sight glasses are off, look through the sight glass openings with a flash light. See that the stabilizing cone and the nozzle have not collected an excessive deposit of carbon.

9. While making the following tests, be sure that the Diesel engine is running in order to keep up the required voltage.

   Place an adapter coupling with the proper orifice on the trainline of the locomotive.

   A 3/4" I.P.S. pipe nipple is used for testing a 3000 pound unit; a 3/8" I.P.S. pipe nipple for the 1600 pound unit.

   If the unit is equipped with a blowoff line, it is not necessary to apply an adapter coupling to the locomotive trainline.

10. Fill the steam generator with water. See that spark is available for ignition.

11. While the motor is running, check the fuel manifold pressure gauge. It should come up to normal operating pressure almost immediately. Low pressure indicates a leak in the fuel suction line.

12. To test the outfire relay, first make certain the atomizing air admission valve is closed. Then turn the control switch to "Run".

    The fire should not light. In about 40 to 60 seconds the outfire relay should shut down the generator. The alarm bell should ring.

13. Start the steam generator. Set the water by-pass regulator at 250 pounds. Allow the generator to run about five to ten minutes.

14. After the generator has reached a steady output it should develop and maintain a gauge pressure of at least 150 pounds. If it does not, the generator is not delivering its full output.

15. Check the water pressure gauge. If the hand does not hold a steady pressure, but wavers back and forth, the water pump is not delivering its full output.

16. Check the water suction line valves. Make sure all valves that should be opened are opened and all that should be closed are closed. Check for leaks in the water suction line.

17. If the water pressure exceeds 400 pounds, the coils are becoming scaled and should be washed out.

    To make certain that sufficient water is entering the coils, open the water pump test valve. Water should flow from this valve without any evidence of air being pumped. When water flows from this valve, the servo drops to the block, the fire goes out and the cutout switch shuts down the generator. This indicates that the servo fuel control is functioning to shut the fire off in the absence of feed water.

18. Check the condition of the fire. If the spray of the fuel nozzle is distorted or if the nozzle fuel pressure is high and insufficient fuel is being burned, the nozzle should be removed and examined.

    If the nozzle tip orifices are out of round or damaged, the nozzle tip should be replaced.

    If the nozzle tip is not damaged but just clogged, clean it with a suitable solvent. Use a wooden splinter to clean out the orifices if necessary. Do not use a wire or metal pick for this purpose.

19. See that the water pump packing is not leaking excessively. A slight leak helps to keep the packing lubricated but excessive leakage should be corrected.

20. See that the servo fuel control has at least three-quarter travel when the control switch is turned to the "Run" position.

21. While the steam generator is operating at full capacity, see that the manifold fuel pressure, the nozzle fuel pressure and the atomizing air pressure are normal.

    The normal operating fuel manifold pressure is about 150 to 155 pounds. Normal operating atomizing air pressure ranges between 70 and 75 pounds on the 3000 pound units and between 30 and 35 pounds on the 1600 pound units.

22. After the generator has operated long enough and has settled down to a steady output, observe the water flow indicator.

    This indicator of the return water flow should cycle from 4 to 12 times a minute on the 3000 pound units. On the 1600 pound units it should cycle 4 to 8 times.

23. Check the generator steam pressure gauge. It should read about the same as the water by-pass regulator setting.

24. Operate the steam generator at full capacity, half capacity and at minimum capacity by throttling with the manual water by-pass valve.

    During this throttling with the manual by-pass valve, the smoke hood cover should not get too hot. The stack gases should be perfectly clear and the stack temperature should not exceed 850° F.

25. After completing these tests, unless the locomotive is going directly into service, the steam generator should be blown down and the coils refilled with water.

TABULATED DATA

Rated Evaporative Capacity, lbs. water per hour	1600 lbs.	3000 lbs.
Water Relief Valve unloading setting	550 lbs.	550 lbs.
Fuel Pressure Regulator set at high fire, to give a manifold pressure of	150-155 lbs.	150-155 lbs.
Atomizing Air Pressure Reducing Valve set at	30- 35 lbs.	70- 75 lbs.
Steam Temp. Limit Control set at (approximately)	450 deg. F.	450 deg. F.
Stack Switch set at	900 deg. F.	900 deg. F.
Outfire Control set to shut down generator after	40 to 60 sec.	40 to 60 sec.
Motor Speed	1750 RPM to 1800 RPM	1750 RPM to 1800 RPM
Blower Speed	2800 RPM	2200 RPM
Water Pump Speed	995 RPM	390 RPM
Water Pressure normally varies from low to high fire	225-350 lbs.	225-350 lbs.
Amperage Draw	30-40 amps	50-70 amps
Lowest Steam Evaporation Rate without cycling	600-800 lbs.	700-900 lbs.
Orifice for Terminal Inspection Test (I.P.S. pipe nipple)	3/8"	3/4"
Trainline Pressure (terminal inspection test)	150 lbs.	150 lbs.

WEEKLY

1. IGNITION: Inspect and clean the spark plugs. The gap between electrodes should be set at exactly 3/16".
2. BELTS AND PULLEYS: Check the alignment and condition of the pulleys. Check the condition and tension of belts. Adjust the tension of belts if necessary. Belts should always be replaced in complete sets. The numbers on the V-belts are sag numbers and should be used to match the belts in sets. A difference of one number up or one number down is permitted in matching a set of belts.
3. WATER PUMP: The pump used on the 4516 steam generator should have the grooves in the piston rods cleaned.
4. FUEL PUMP: Inspect for leaks and loose mounting. Check the flexible coupling.
5. VALVE STEMS: Check leaks -- repack stuffing boxes where necessary.
6. STEAM TEMPERATURE LIMIT CONTROL: Check the adjustment and make sure the operating rod moves freely.

MONTHLY

1. WASH OUT: Descale the steam generator coils if the feed water pressure goes up to 425 lbs. during operation of the steam generator. Make record of date.
2. SOOT: Remove the inspection plates and blow soot from coils with 100 lbs. air pressure; use wire brush where necessary. Clean all soot from the base of the coils. Make a hammer test on the outer coils to detect weakened spots.
3. RELAYS: Inspect all contacts on relays and on all switches on the electrical devices. Clean or replace as required.

4. WATER TANK: Drain and flush out the water supply tanks.

5. MOTOR: Check commutator and brushes, take off plate and clean collector rings (slip ring).

6. WATER TREATMENT TANK OR STRAINER TANK: Drain sediment out of tank.

7. TREATMENT INJECTOR (where used): Clean the sediment out of the treatment filter in the line between the solution tank and injector pump.

8. MAGNETIC TRAINLINE SHUTOFF VALVE: Repack the valve stem.

9. SERVO-FUEL CONTROL: Clean the diaphragm chamber and the water metering valve stem and seat. Renew the diaphragm if it shows wear or loss of flexibility and strength.

10. FUEL FILTERS: Drain the suction line filter. Clean the filter element in the pressure line.

11. STEAM TRAPS: Clean and check operation.

QUARTERLY

1. STACK SWITCH: Inspect and check its setting. Test the helix in a test furnace -- high temperature contacts should open at 900° F. Low temperature contacts should close at 250° F. on DRK units, at 300° F. on OK units.

2. OIL FILTER: Clean the filter element on the suction line filter.

3. STEAM TEMPERATURE LIMIT CONTROL: Renew the control shaft packing and reset the control.

4. TREATMENT INJECTOR PUMP (where used): Replace the diaphragm and check the valve for scoring and/or improper seating.

5. WATER PUMP: Check the water pump packing.

SEMI-ANNUALLY

1. DIAPHRAGMS: Replace diaphragms in the DRK fuel spray head, servo-fuel control and water by-pass regulator.

2. MOTOR: Blow out dirt with dry compressed air at not over 40 lbs. pressure. Direct the air flow so that the dirt is blown out of the end shields and away from the armature. Examine brushes, brush-holders, commutator, commutator clamping ring and collector rings; clean holders and check brush pressure and position; wipe commutator and brushes and clean with a cloth dampened in carbon tetrachloride. Replace brushes that are more than half worn. Be sure anchor bolts are secure and that covers are securely fastened.

3. CHECK VALVES: Inspect and clean. Replace or lap valve and seat if worn.

4. WATER RELIEF VALVE: Take apart and clean.

ANNUALLY

1. WATER SUPPLY TANK: When washing out the steam generator, also wash out the water supply tank and the water suction line between the main storage tank and the treater.

2. STACK SWITCH: Check in testing furnace and replace if inaccurate.

3. WATER PUMP: Overhaul the water pump or send it to the Vapor Heating Corporation for factory overhauling.

4. WATER BY-PASS REGULATOR: Overhaul.

5. SERVO-FUEL CONTROL: Inspect and overhaul or change out and send to the Vapor Heating Corporation.

6. REMOTE CONTROL EQUIPMENT: Inspect and overhaul electric equipment and magnetic trainline valve.

7. SOLENOID AND RELAY COILS: Test the insulation resistance of all coils and the ignition transformer (Megger Test).

8. HYDROSTATIC TEST: Test the steam generator by subjecting it to hydrostatic pressure 25% above the working steam pressure.

9. SEPARATOR BLOWDOWN VALVE: Inspect the air cylinder and lubricate. Take up the wear in the operating lever.

10. BLOWER FAN: Check fan bearings for wear; remove and clean the fan and clean the air inlet duct in the roof.

11. MOTOR CONVERTER: Overhaul the motor and converter. Check the sealed bearings. If it is necessary to grease the bearings, do not use a high pressure grease gun -- it will force out the grease seal and injure the bearing surfaces. Release the snap ring which holds the grease seal in place, remove the bearing and wash it thoroughly in solvent. Then repack the bearing, replace the grease seal and reinstall the bearing.

    It is recommended that the grease fittings on the bearing housing be removed and pipe plugs inserted.

12. FIRE POT: Inspect and repair if necessary.

13. COIL BLOWDOWN VALVE: Inspect for leaks and tight seating of swing gate valve.

14. COIL RETAINER AND PADS: Check and replace if the coil pads are torn or burned or if the coil retainer is flaky and burned. See that the coil refractory and refractory container are not cracked or chipped.

LUBRICATION

Refer to Lubrication Schedule.

VAPOR-CLARKSON TYPE CFK-4225

Trip

1. Terminal inspection should be carried on with engine running.

2. Start the steam generator and check the water pressure. Water pump delivery gauge should be steady and should not show a pressure of more than 100 lbs. above normal. A pressure in excess of this will indicate that the coils in the steam generator need to be washed.

3. Check pressure switch, relays and ignition by operation of stop valve. Turn the pressure switch hand wheel slowly over the whole pressure range up and down. Speed of motor should increase and decrease proportionately.

4. The operation of fire should be checked at both low range or "START" position and high range or "RUN" position to determine whether fuel control is properly adjusted. The feed water temperature at the steam generator feed check should remain approximately the same, that is about 100° F., at both high and low fire.

5. Check for oil and water leaks.

6. Empty drip pan under water pump packing. A slight leakage is normal and advisable as it keeps the packing lubricated. Excessive leakage should be corrected by taking up the plunger packing through tightening of the locknuts on the packing take-up flange. Do not over tighten.

7. Check for excessive temperature of motor and water pump crankcase.

8. Clean screen in water treater tank. Also, inspect and clean openings in water treater tube (lance).

9. Check the fuel control by opening the water pump test valve. This should put out the fire. It is important that the packings on the fuel control are free. A little sweating is permissible. Excessive leakage should be corrected.

10. Pull out stack switch plug connector and steam generator should stop immediately. This checks the alarm system, if used, which should start ringing. Replace plug connector, reset operating switch to "OFF" and steam generator should restart.

11. After the above check is completed, close stop valve and set up the pressure switch until steam generator builds up pressure to 200 pounds. Then stop steam generator and blow coils down to 75 pounds pressure. Close coil blowdown valve and with the remaining pressure blow down the steam separator. Close separator blowdown valve.

12. While fire is off and fire pot is still hot, observe if there is any excessive carbon in the fire pot and stabilizing cone. If so, clean out. The coils should be bright.

13. After the coils and the steam separator have been blown down, close the atomizing air pressure admission valve and attempt to start steam generator by turning operating switch to "START" or "RUN" position. The low fire contacts on the stack switch should shut down the motor in about 90 to 120 seconds. This will test the operation of these devices.

14. Open the atomizing air pressure admission valve and reset the operating switch to "OFF" position. Refill the steam generator in the regular manner with water up to the bottom try-cock on steam generator.

NOTE: Allow gauges to settle before taking reading. Never attempt to adjust gauges equipped with snubbers.

WEEKLY

1. Remove burner face plate and clean out combustion chamber and fire pot. Excessive carbon in the fire pot denotes defective spray nozzle.

2. Inspect and clean spray nozzle. Replace, if defective.

3. Clean fuel strainer screens.

4. Inspect and clean spark plugs. Gap should be 3/16" on the transformer ignition plugs. Electrodes should be just outside of spray cone.

5. If dirty, clean screen of water treater by blowing out with air pressure and washing out with boiler washing compound. Be sure that the top is firmly fastened in place after the operation is completed.

6. Remove plug from bottom of Purolator oil filter and carefully drain out all sediment.

7. Drain the Zenith fuel oil filter.

8. Check packing on water pump. Tighten up the packing, as often as necessary, to stop excessive drip.

9. Clean out the groove in the piston rods of the water pump with a cloth to keep dust from accumulating, in order to prevent scoring of pistons, which would allow water to pass to crankcase.

10. Check belt adjustment.

11. See that the peep hole glasses are clean.

12. Wipe all parts of steam generator clean.

13. After above operations are carried out, steam generator should be started and tested.

MONTHLY

1. Wash out steam generator if necessary.

2. Clean and check motors including all motor brushes.

3. Inspect all contacts of relays and clean if necessary.

4. Clean out dash pots on pressure switch and on any other dash pot relays provided.

5. Check tension of belts; adjust if necessary. Replace belts as soon as they show excessive wear. Both belts of a pair should be replaced together.

6. Remove inspection plates or jacket of steam generator, inspect and clean coils if necessary. Clean out all soot at base of coils.

7. Flush out main water tanks.

QUARTERLY

1. Check stack switch for accurate setting by placing helix of this switch in a stack that can be brought up to 900° F., at which temperature the contacts should open.

2. Soot blower valves should be inspected for tight seating and ground if necessary. Coil blowdown and separator blowdown valves should also be inspected for tight seating.

3. Clean filter elements on the fuel filters.

SEMI-ANNUALLY

1. Replace diaphragms in the fuel control and in both of the pressure switches.

ANNUALLY

1. Wash out water suction lines between main storage tank and water treater.

2. Apply new helix to stack switch.

LUBRICATION SCHEDULE
660 HP AND 1000 HP SWITCHER LOCOMOTIVES

DAILY

ITEM	EQUIPMENT	LUBRICANT	METHOD
1.	Air Compressor	Westinghouse Spec. M-251 Preferred or Engine Lube Oil	Check level. Change oil as examination indicates.
2.	Diesel Engine	Engine Lube Oil	Check level. Change oil as examination indicates.
3.	Engine Governor	Governor Oil	Check level. Maintain level at top of sight glass.
4.	Journal Box Friction Bearing	Car Oil	Saturate waste. Check wick to end block.
5.	Pedestal Liners	Car Oil	Add oil to pockets.

MONTHLY

Repeat Work Listed Under "Daily"			
6.	Air Brakes	—	Follow manufacturer's instructions
7.	Auxiliary Generator and Exciter Drive Shaft Bearings	G. E. Ball Bearing Grease D6A2A3	Add 1/4 ounce.
8.	Battery	Petroleum Jelly	Coat Terminals.
9.	Bell Ringer	Light Machine Oil	Lubricate working parts.
10.	Brake Rigging	Car Oil	Lubricate pins and bushings.
11.	Center Plates	Car Oil	Fill oil cup.
12.	Controller	Stazrite No. 30 or Equivalent	Segments - Apply thin film.
		Light Machine Oil	End bearings - Add 3 or 4 drops.
13.	Coupler	Alemite Grease	Lubricate.
14.	Coupler Pin and Carrier	Car Oil	Lubricate with hand oiler.
15.	Door and Window Hardware	Light Machine Oil	Lubricate with hand oiler.
16.	Electro-Pneumatic Contactors	G.E. PC No. 1 Oil	Oil hole in cyl.- Add 3 or 4 drops.
		Stazrite No. 30 or Equivalent	Interlocks - Apply thin film.
17.	Flexible Coupling (Falk)	Marfak No. 3 HD Grease or equivalent	Add lubricant.

MONTHLY (cont'd)

ITEM	EQUIPMENT	LUBRICANT	METHOD
18.	Flexible Coupling (Fast)	Crater Compound No. 1 or equivalent	Add lubricant.
19.	Flexible Coupling (Thomas)	—	No lubrication required.
20.	Fuel Pump Racks	Light Machine Oil	Lubricate with 3 or 4 drops.
21.	Governor Linkage	Light Machine Oil	Lubricate pins and bushings.
22.	Push Button Switch Segments	Stazrite No. 30 or equivalent	Apply thin film.
23.	Radiator Fan Drive Shaft Bearings	G.E. Ball Bearing Grease D6A2A3	Grease lightly.
24.	Radiator Fan Gear Box (All GA-14 type except GA-14-F)	Engine Lube Oil	Housing - Fill when level is 1/4" down.
25.	Radiator Fan Gear Box (type GA-14-F)	Engine Lube Oil	Fill up to level warning plate.
26.	Radiator Fan Idler Pulley Bearings	G.E. Ball Bearing Grease D6A2A3	Add 1 ounce to each bearing.
27.	Radiator Shutter Cable	Alemite Grease	Lubricate.
28.	Radiator Shutters and Linkage	Car Oil	Lubricate with hand oiler.
29.	Reverser	No. 2 Cup Grease	Drum bearings - Give grease cup 1 or 2 turns.
		Stazrite No. 30 or equivalent	Segments - Apply thin film.
			Control fingers - Apply thin film.
30.	Side Bearings	Alemite Grease	Apply thin film to bearing surface.
31.	Throttle Linkage	Car Oil	Lubricate with hand oiler.
32.	Traction Motor Axle Bearings	Electric Car Oil	Check level - Minimum 1-3/4" - Maximum 3-1/2".
33.	Traction Motor Blower Drive Shaft Bearings	G.E. Ball Bearing Grease - D6A2A3	Add 1/4 ounce to each bearing.
34.	Traction Motor Gear Case	Crater Compound No. 5 (Summer) No. 2 (Winter) or equivalent.	Add 2 pounds - Maintain heavy film of grease on gear teeth - initial filling approx. 10 lbs.

QUARTERLY

ITEM	EQUIPMENT	LUBRICANT	METHOD
	Repeat Work Listed Under "Monthly"		
35.	Controller	Alemite Grease	Notching segment - Lubricate.
36.	Hand Brake	Engine Lube Oil	Bearings - Lubricate.
		Elemite Grease	Chain - Lubricate points of sliding contacts.
37.	Pedestal Liners	Car Oil	Clean pockets and refill.
38.	Voltage Regulator	Light Machine Oil	Pins and linkage - Lubricate.
39.	Windshield Wipers	Light Machine Oil	Lubricate working parts.

SEMI-ANNUALLY

	Repeat Work Listed Under "Quarterly"		
40.	Auxiliary Generator and Exciter Bearings	G.E. Ball Bearing Grease - D6A2A3	Add 1/4 ounce to each bearing.
41.	Radiator Fan Gear Box (All GA-14 type except GA-14-F)	G.E. Ball Bearing Grease - D6A2A3	Vertical Shaft Bearing - Add 1 oz.
			Horizontal Shaft Bearing - Add 3 oz.
42.	Traction Motor Axle Bearings	Electric Car Oil	Repack with long fiber all wool waste treated with oil. Also repack at wheel change.

ANNUALLY

	Repeat Work Listed Under "Semi-Annually"		
43.	Cab Heater Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Repack.
44.	Electro-Pneumatic Contactors	G.E. PC No. 1 Oil	Air Cylinder Piston Leathers - - Soften in oil.
		G.E. PC No. 2 Grease	Air Cylinders - - Apply thin film on walls.
45.	Flexible Coupling (Falk)	Marfak No. 3 HD or equivalent	Repack.
46.	Flexible Coupling (Fast)	Crater Compound No. 1 or equivalent	Repack.
47.	Fuel Pump Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Repack.
48.	Radiator Fan Gear Box (All except GA-14-F)	Engine Lube Oil	Housing -- Drain and refill.

ITEM EQUIPMENT LUBRICANT METHOD

ANNUALLY (cont,d)

49.	Radiator Fan Gear Box (type GA-14-F)	Engine Lube Oil	Drain and refill.
50.	Reverser	G.E. PC No. 1 Oil	Air Cylinder Piston Leathers - - Soften in oil.
		G.E. PC No. 2 Grease	Air Cylinder - Apply thin film on walls.
51.	Traction Generator Bearing	Medium Heavy Machine Oil	Add 1/4 pint.
		G.E. Ball Bearing Grease D6A2A3	17 oz. required when repacking.
52.	Traction Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Commutator end - Add 2 ounces. Initial filling 10 ounces.
			Pinion end - Add 4 ounces. Initial filling 22 ounces.

TRACTION MOTOR ARMATURE BEARING LUBRICATION

The traction motor armature bearings on both the 660 and 1000 hp switcher and road switcher locomotives are now lubricated with G-E ball bearing grease, Type D6A2C4, when the motor is assembled. Grease pipes, formerly used in bearing caps, have been eliminated or replaced by a pipe plug screwed into the tapped hole. These plugs are either welded to cap (using bronze welding rod) or sealed with a metal cover, welded to cap and marked, "DO NOT LUBRICATE". This is to prevent the addition of grease between overhauls. Do not mix D6A2C4 grease with any other grease or a lubrication failure may result.

DO NOT ADD GREASE to bearings until motor is disassembled for overhaul.

LUBRICATION SCHEDULE
1000 HP ROAD SWITCHER LOCOMOTIVE

ITEM EQUIPMENT LUBRICANT METHOD

DAILY OR TRIP

1.	Air Compressor	Westinghouse Spec. M-251 Preferred or Engine Lube Oil	Check level. Change oil as examination indicates.
2.	Diesel Engine	Engine Lube Oil	Check level. Change oil as examination indicates.
3.	Engine Governor	Governor Oil	Check level. Maintain level at top of sight glass.
4.	Journal Box Friction Bearing	Car Oil	Saturate waste. Check wick to end block.
5.	Pedestal Liners	Car Oil	Add oil to pockets.
6.	Steam Generator Vapor-Clarkson Type -- DRK-4516 - 4530 OK -4616 - 4630	No. 2 Cup Grease	Blower Fan Bearing - Lubricate.
			Belt tension adjuster bearing - lubricate.
		Engine Lube Oil	Damper control rod linkage - lubricate.
			Damper bearings - Lubricate.
			Water pump - Maintain oil level at high mark on bayonet gauge (DRK-4516 - OK-4616).
		Automotive Oil SAE 20 (Winter) SAE 30 (Summer)	Water pump - check oil level at petcock, capacity 3 quarts. (DRK-4530 - OK-4630).
7.	Steam Generator Vapor-Clarkson Type CFK-4225	Engine Lube Oil	Water pump - Maintain oil level at mark on bayonet gauge.

MONTHLY

	Repeat Work Listed Under "Daily or Trip"		
8.	Air Brakes	—	Follow manufacturer's instructions
9.	Auxiliary Generator and exciter drive shaft bearings	G.E. Ball Bearing Grease D6A2A3	Add 1/4 ounce.
10.	Battery	Petroleum Jelly	Coat terminals.
11.	Bell Ringer	Light Machine Oil	Lubricate working parts.
12.	Brake Rigging	Car Oil	Lubricate pins and bushings.

MONTHLY (cont'd)

ITEM	EQUIPMENT	LUBRICANT	METHOD
13.	Center Plates	Car Oil	Fill oil cup.
14.	Controller	Stazrite No. 30 or equivalent	Segments - Apply thin film.
		Light Machine Oil	End Bearings - add 3 or 4 drops.
15.	Coupler	Alemite Grease	Lubricate.
16.	Coupler Pin and Carrier	Car Oil	Lubricate with hand oiler.
17.	Door and Window Hardware	Light Machine Oil	Lubricate with hand oiler.
18.	Electro-Pneumatic Contactors	G.E. PC No. 1 oil	Oil hole in cylinder - - Add 3 or 4 drops.
		Stazrite No. 30 or equivalent	Interlocks - Apply thin film.
19.	Flexible Coupling (Falk)	Marfak No. 3 HD Grease or equiv.	Add lubricant.
20.	Flexible Coupling (Fast)	Crater Compound No. 1 or equiv.	Add lubricant.
21.	Flexible Coupling (Thomas)	—	No lubrication required.
22.	Fuel Pump Racks	Light Machine Oil	Lubricate with 3 or 4 drops.
23.	Governor Linkage	Light Machine Oil	Lubricate pins and bushings.
24.	Push button switch segments	Stazrite No. 30 or equivalent	Apply thin film.
25.	Radiator Fan Drive Shaft Bearings	G.E. Ball Bearing Grease D6A2A3	Grease lightly.
26.	Radiator Fan Gear Box (All GA-14 type except GA-14-F)	Engine Lube Oil	Housing - Fill when level is 1/4" down.
27.	Radiator Fan Gear Box (Type GA-14-F)	Engine Lube Oil	Fill up to level warning plate.
28.	Radiator Fan Idler Pulley Bearing	G.E. Ball Bearing Grease D6A2A3	Add 1 ounce to each bearing.
29.	Radiator Shutter Cable	Alemite Grease	Lubricate.
30.	Radiator Shutters and Linkage	Car Oil	Lubricate with hand oiler.

MONTHLY (cont'd)

ITEM	EQUIPMENT	LUBRICANT	METHOD
31.	Reverser	No. 2 Cup Grease	Drum Bearings - Give grease cup 1 to 2 turns.
		Stazrite No. 30 or equivalent	Segments - Apply thin film.
			Control fingers - Apply thin film.
32.	Side Bearings	Alemite Grease	Apply thin film to bearing surface.
33.	Steam Generator Vapor-Clarkson DRK-4516 OK -4616	Engine Lube Oil	Water Pump - change oil.
		High Temperature Grease	Stack Switch Bearing - Apply light coating.
		Dashpot Oil	Dashpot Relay - Fill dashpot if necessary.
34.	Steam Generator Vapor Car Type CFK-4225	No. 2 Cup Grease	Motor Bearings - Lubricate.
			Blower Fan Bearings - Lubricate.
35.	Throttle Linkage	Car Oil	Lubricate with hand oiler.
36.	Traction Motor Axle Bearings	Electric Car Oil	Check level. Minimum 1-3/4", Maximum 3-1/2".
37.	Traction Motor Blower Drive Shaft Bearings	G.E. Ball Bearing Grease D6A2A3	Add 1/4 ounce to each bearing.
38.	Traction Motor Gear Case	Crater Compound No. 5 (Summer) No. 2 (Winter) or equivalent	Add 2 pounds. Maintain heavy film of grease on gear teeth - initial filling approximately 10 pounds.

QUARTERLY

Repeat Work Listed Under "Monthly"			
39.	Controller	Alemite Grease	Notching Segment - Lubricate.
40.	Hand Brake	Engine Lube Oil	Bearings - Lubricate.
		Alemite Grease	Chain - Lubricate points of sliding contacts.
41.	Pedestal Liners	Car Oil	Clean pockets and refill.
42.	Steam Generator Vapor-Clarkson Type - CFK-4225	Light Machine Oil	Pressure switch - Lubricate all moving parts.
		No. 2 Cup Grease	Water pump crankshaft bearing caps - Repack half full.
43.	Voltage Regulator	Light Machine Oil	Pins and linkage - Lubricate.
44.	Windshield Wipers	Light Machine Oil	Lubricate working parts.
45.	Auxiliary Generator and Exciter Bearings	G.E. Ball Bearing Grease D6A2A3	Add 1/4 ounce to each bearing.

ITEM EQUIPMENT LUBRICANT METHOD

SEMI-ANNUALLY

	Repeat Work Lister Under "Quarterly"		
46.	Radiator Fan Gear Box (All GA-14 types except GA-14-F).	G.E. Ball Bearing Grease D6A2A3	Vertical Shaft Bearing - Add 1 oz. Horizontal shaft bearing - Add 3 oz.
47.	Traction Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Pinion end - Add 4 ounces. Initial filling 22 ounces.
48.	Traction Motor Axle Bearings	Electric Car Oil	Repack with long fiber all wool waste treated with oil. Repack at wheel change.

ANNUALLY

	Repeat Work Listed Under "Semi-Annually"		
49.	Cab Heater Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Repack.
50.	Electro-Pneumatic Contactors	G.E. PC No. 1 Oil	Air Cylinder Piston Leathers - - Soften in oil.
		G.E. PC No. 2 Grease	Air Cylinders - - Apply thin film on walls.
51.	Flexible Coupling (Fast)	Crater Compound No. 1 or equivalent	Repack.
52.	Flexible Coupling (Falk)	Marfak No. 3 HD or equivalent.	Repack.
53.	Fuel Pump Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Repack.
54.	Radiator Fan Gear Box (All except GA-14-F).	Engine Lube Oil	Housing - Drain and refill.
55.	Radiator Fan Gear Box (Type GA-14-F)	Engine Lube Oil	Drain and refill.
56.	Reverser	G.E. PC No. 1 Oil	Air Cylinder Piston Leathers - - Soften in oil.
		G.E. PC No. 2 Grease	Air Cylinders - Apply thin film on walls.
57.	Steam Generator Vapor-Clarkson DRK-4516 - 4530 OK -4616 - 4630	Dow Corning DC 44 or equivalent	Motor converter bearings-Lubricate.
58.	Traction Generator Bearing	Medium heavy Machine Oil	Add 1/4 pint.
		G.E. Ball Bearing Grease D6A2A3	17 ounces required when repacking.
59.	Traction Motor Armature Bearings	G.E. Ball Bearing Grease D6A2A3	Commutator end - Add 2 ounces Initial filling 10 ounces.

LUBRICANTS

The following is a list of the lubricants referred to on the preceding pages.

Alemite Grease

Good Grade

Car Oil

Good Grade conforming to AAR classification

Crater Compound

	No. 1	No. 2
Appearance		
By transmitted light	Opaque	Opaque
By reflected light	Black	Black
Gravity, °API	13.4	11.7
Viscosity		
Saybolt Furol, Sec. @ 210° F	105	208
Corrosion, Copper Strip @ 212° F	Neg.	Neg.

Cup Grease No. 2

Good Grade Calcium Soap Grease

Consistency, ASTM	
Worked @ 77° F	250-300
Viscosity of Mineral Oil	
SSU @ 100° F	300-325

Dash Pot Oil —

Dow Corning D.C. 44

Worked Consistency	250-270

Electric Car Oil

Good Grade (summer and winter)

Engine Lube Oil

Viscosity	
Max. SSU @ 100° F	1300
SSU @ 210° F	65-80
Flash Point, Min. °F	390
Pour Point, Max. °F	35
Carbon Residue, Max. %	.5
Water and Sediment	Trace

G.E. Ball Bearing Grease D6A2A3

Worked Consistency	270-290
Flow Point - °F Min.	290
Mineral Oil Vis. SSU @ 100° F	220-400
Free Alkali % Max.	.35
Free Acid	Nil.
Water % Max.	.20
Ash % Max.	5.0
Base	Sodium-Calcium with anti-oxident

G.E. PC No. 1 Oil

Flash Point - Min.	390° F.
Fire Point - Min.	400° F.
Viscosity S.U.V. sec. at 100° F.	230 - 250
Viscosity S.U.V. sec. at 210° F.	48 - 52
Viscosity Index - Min.	100
Pour Point - Max.	-10° F.
* Aniline Point - Min.	203° F.
Neutralization Number - Max.	.075
Oxidation Inhibitor	Permissible
Corrosion Inhibitor	Permissible
Detergents	None

* Lower values objectionable because of swelling of synthetic compounds.

G.F. PC No. 2 Grease

Worked Consistency - ASTM - M.M./10	365 - 385
Unworked Consistency - ASTM - M.M./10	360 - 385
Dropping Point, ASTM Min.	300° F.
Mineral Oil, Viscosity at 100° F.	200 - 300
Soap Base	Sodium
Free Alkali as NAOH % Max.	.35
Free Acid as Oleic % Max.	Nil.

Governor Oil

SAE 40-50 Straight Mineral Engine Oil

High Temperature Grease

Light Machine Oil

Marfak No. 3 H.D.

Consistency, ASTM	
Unworked @ 77° F.	230
Worked @ 77° F.	230
Dropping Point, Deg. F.	425
Soap, Sodium, %	15.5
Water, %	.10
Corrosion, Copper Strip @ 167° F.	Neg.
Mineral Oil Vis., SSU @ 210° F.	92.9

Medium Heavy Machine Oil

Flash Point, Min. °F.	370
Fire Point, Min. °F.	420
Viscosity SSU @ 100° F.	550 - 580
Viscosity SSU @ 210° F.	53 - 56

Petroleum Jelly

SAE 20 Automotive Oil

SAE 30 Automotive Oil

Stazrite No. 30

Worked Consistency	210 - 240
Flow Point °F.	450
Mineral Oil Viscosity, SSU @ 100° F.	400 - 2000
Free Alkali % Max.	.60
Free Acid	Nil.
Water % Max.	.20
Ash % Max.	5.0
Base	Sodium - Calcium, or Sodium or Lithium

Westinghouse Spec. #4 Dec. 1, 1949 M-251

Use

An oil suitable for Diesel engine and motor driven compressors which are subjected to heavy duty, such as those running for long periods in relatively warm places. It is not recommended for compressors in which the oil itself is subjected to extremely low temperatures.

General

This oil shall be well refined mineral oil, free from saponifiable and fatty oils, mineral soaps, sulfur and fillers. Additives such as oxidation inhibitors and detergents are permissible. Detergent oils must be used with caution in compressors which have previously been run with non-detergent oils.

Flash Point	The flash point shall not be below 400° F. (open cup)
Fire Point	The fire point shall not be below 450° F. (open cup)
Pour Point	The pour point shall not be higher than 25° F.
Viscosity	The viscosity at 100° F. shall not be less than 550 seconds and not more than 1350 seconds (S.U.V.). The viscosity at 210° F. shall not be less than 58 seconds (S.U.V.). (See notes 1 and 2.)
Methods of Testing	All the methods of testing used shall be according to the American Society for Testing Materials.
Note 1:	Some of the higher viscosity oils included in this specification become very thick at low temperatures (below freezing) and are not suitable for compressors starting at low temperatures. When it is necessary to start compressors at temperatures below freezing, oils with a viscosity in the lower range of this specification should be selected.
Note 2:	If difficulty is encountered with excessive oil vapors in the compressed air, it is probably due to an oil with a low viscosity index being used. In that case an oil with a higher viscosity index is recommended.

SUBJECT	Pages 1029-32 660 & 1000 SW Item No.	Pages 1033-36 1000 RS Item No.
Air Brakes	6	8
Air Compressor	1	1
Auxiliary Generator and Exciter Bearings	40	45
Auxiliary Generator and Exciter Drive Shaft Bearings	7	9
Battery	8	10
Bell Ringer	9	11
Brake Rigging	10	12
Cab Heater Armature Bearings	43	49
Center Plates	11	13
Contactors - Electro-Pneumatic	16, 44	18, 50
Controller	12, 35	14, 39
Coupler	13	15
Coupler Pin and Carrier	14	16
Diesel Engine	2	2
Door and Window Hardware	15	17
Engine Governor	3	3
Flexible Coupling		
Falk	17, 45	19, 52
Fast	18, 46	20, 51
Thomas	19	21
Fuel Pump Motor Armature Bearings	47	53
Fuel Pump Racks	20	22
Governor, Engine	3	3
Governor Linkage	21	23
Hand Brake	36	40
Journal Box Friction Bearing	4	4
Pedestal Liners	5, 37	5, 41
Push Button Switch Segments	22	24
Radiator Fan Drive Shaft Bearings	23	25
Radiator Fan Gear Box	24, 41, 48	26, 40, 54
Radiator Fan Gear Box (Type GA-14-F)	25, 49	27, 55
Radiator Fan Idler Pulley Bearings	26	28
Radiator Shutter Cable	27	29
Radiator Shutters and Linkage	28	30
Reverser	29, 50	31, 56
Side Bearings	30	32
Steam Generator		6
Belt Tension Adjuster Bearing		6, 34
Blower Fan Bearing		6
Damper Bearing		6
Damper Control Rod Linkage		33
Dashpot Relay		34
Motor Bearings		57
Motor Convertor Bearings		42
Pressure Switch		33
Stack Switch Bearing		6, 7, 33
Water Pump		42
Water Pump Crankshaft Bearing Caps		
Throttle Linkage	31	35
Traction Generator Bearing	51	58

SUBJECT	Pages 1029-32 660 & 1000 SW Item No.	Pages 1033-36 1000 RS Item No.
Traction Motor Armature Bearings	52	47, 59
Traction Motor Axle Bearings	32, 42	36, 48
Traction Motor Blower Drive Shaft Bearings	33	37
Traction Motor Gear Case	34	38
Voltage Regulator	38	43
Window and Door Hardware	15	17
Windshield Wipers	39	44

Device Symbol	Device Parts	Connec. Diagram	Operating Test	Data	Operation
B	Coil Main Contacts Interlocks	1210 1209 1209	1301	1104	1312
CL	Coil Main Contacts	1206 1210	1302	1104	1312
CR1	Coil Main Contacts	1212 1213	1304	1105	1312
CR2-(MU ONLY)	Coil Main Contacts	1213 1207		1105	1312
EF	Coil Main Contacts Interlocks	1212,13 1207,8 1210,11	1304 1305	1105	1312
GF	Coil Main Contacts Interlocks	1212,13 1208 1206	1304 1305	1106	1313
GR	Coil Main Contacts Interlocks	1206 1211 1211	1305	1106	1314
GS1	Coil Main Contacts Interlocks	1210 1208 1211	1302	1107	1315

Device Symbol	Device Parts	Connec. Diagram	Operating Test	Data	Operation
GS2	Coil	1210	1302	1107	1315
	Main Contacts	1208			
	Interlocks	1211			
M1	Coil	1212	1305	1107	1315
	Main Contacts	1206			
	Interlocks	1206			
M2	Coil	1212	1305	1107	1315
	Main Contacts	1206			
RC	Shunt Coil	1209		1107	1315
	Series Coil	1209			
	Diff. Coil	1209			
	Main Contacts	1210			
S	Coil	1212	1304	1108	1315
	Main Contacts	1206	1305		
	Interlocks	1211			
SP1	Coil	1212	1304	1108	1316
	Main Contacts	1206	1305		
	Interlocks	1212			
SP2	Coil	1212	1304	1108	1316
	Main Contacts	1206	1305		
	Interlocks	1212			

Device Symbol	Device Parts	Connec. Diagram	Operating Test	Data	Operation
T1	Coil (MU only)	1213		1108	1320
T2	Coil (MU only)	1213		1108	1320
T3	Coil (MU only)	1213		1108	1320
V	Shunt Coil	1206		1108	1316
	Series Coil	1206			
	Main Contacts	1212			
WS1	Coil	1206	1301	1109	1318
	Main Contacts	1210,11			
WS2	Coil	1206	1301	1109	1318
	Main Contacts	1210,11			
X	Fixed Coil	1209		1109	1318
	Floating Coil	1209			
	Main Contacts	1209			
Controller Locking Coil	Main Contacts	1212	1303		1319
	Interlocks				
101	Main Contacts	1212	1303	1110	
110	Main Contacts	1207		1111	
113	Coil	1210	1302	1111	1314
	Main Contacts	1210			
115	Main Contacts	1210	1302	1111	
118	Coil	1210	1301		1319

SYMBOL	NAME	FUNCTION	DATA
A	Aux.Gen.	Supplies power for battery-charging and control circuits.	
B	Battery Charging Contactor	Connects battery to auxiliary generator	Tip Gap - 11-13/32 in. Wipe - 5-7/32 in. Lb Pressure - Initial 1.5-2 Final 3-4 Coil Resis. - 299 Amps to Operate - .120 Continuous - .242
BA	Battery Ammeter	Shows battery charging or discharging in amperes.	
BR	Battery Charging Resistor	Limits battery charging current.	
CL	Current Limit Relay	Lights overload indicating light.	Tip Gap - .030-.060 Wipe - None Pickup - 900 amps

SYMBOL	NAME	FUNCTION	DATA
CR1	Control Relay	Series to series-parallel transfer.	Tip Gap - 7-8/32 in. Wipe - 2-4/32 in. Coil Resis. - 299 Dropout - 80% of Pickup
CR2	Control Relay	Allows "SOFT START" (MU only)	Same as CR1
E	Exciter	Energizes main-generator field.	
EF	Exciter Field Contactor	Connects exciter field to battery.	Tip Gap - 11-13/32 in. Wipe - 5-7/32 in. Lb Pressure - Initial 1.5-2 Final 3-4 Coil Resis. - 299 Amps to Operate - .12 Continuous - .242
EFR	Exciter Field Resistors	Battery and self-excitation adjusting resistors.	

SYMBOL	NAME	FUNCTION	DATA
FP	Fuel Pump	Pumps fuel oil to high-pressure header.	
G	Main Generator	Furnishes power to traction motors.	
GF	Main Gen. Fld. Contactor	Connects main-generator field to exciter.	Same as EF.
GFR	Main Gen. Fld.Resis.	Discharges field when GF opens.	
GR	Ground Relay	Opens EF and GF, when a ground occurs, to de-energize traction-motor circuits.	Tip Gap - 9-11/32 in. Wipe - 3-4/32 in. Coil Resis. - .0735 Pickup - Approx. 10 amps
GRR	Grd.Relay Resistors	Limits current in ground relay coil.	

SYMBOL	NAME	FUNCTION	DATA
GS1 GS2	Engine-Start Contactors	Connects battery to start field of main generator to crank engine	Tip Gap - 9-11/32 in. Wipe - 11-13/32 in. Lb Pressure - Initial 7-10 Final 18-22 Coil Resis. - 25.2 Amps to Operate - .55 Continuous - 1.03
M1,M2	Field-Shunting Contactors	Connects resistors in parallel with motor fields resulting in reduced or shunted field operation for higher locomotive speeds.	Tip Gap - 9-11/32 in. Wipe - 11-13/32 in. Lb Pressure - Initial 2-3 Final 7-10 Coil Resis. - 153 Amps to Operate - .22 Continuous - .418
RC	Reverse-Current Relay	Controls battery-charging contactor.	Coil Resistances Shunt - 29.4 Differential -279 Series - .00287
RCR	RC Relay Resistor	Controls closing and opening of reverse-current relay contacts.	

SYMBOL	NAME	FUNCTION	DATA
S	Series Motor Contactor	Connects traction motors in series.	See Maintenance Manual.
SP1,SP2	Series-Parallel Motor Contactor	Connects traction motors in series-parallel.	Same as "S".
T1, T2, T3 (MU only)	Throttle Valves	Determines speed spring setting on governor through a linkage which the governor transposes into rack setting.	
V	Transfer and Fld. Shunting Relay	In response to predetermined values of main-generator current and voltage, controls transition, series to series-parallel, to reduced field and back to series-parallel.	Tip Gap - 1/16 in. Wipe - 1/16 in. Coil Resis. - Shunt 550 Series 1.41
VR1 to VR7 Incl.	Transfer Relay Resistors	Controls closing and opening of transition relay contacts.	

SYMBOL	NAME	FUNCTION	DATA
WS1,WS2	Wheel-Slip Relays	Rings alarm buzzer when wheels slip, and removes power from main generator. Some units do not have the power-removal feature.	Tip Gap - 1/32-3/64 in. Coil Resis. - 525 Pickup - 0.075 amp Dropout - 90% of pickup
WSR1, WSR2	WS Relay Resistors	Provides a mid-potential point for wheel-slip relays.	
X	Voltage-Regulating Relay	Controls auxiliary-generator voltage.	Coil Resistances Operating - 10.15 Shunt - 14. Series - 0.245
--	Reverser	Reverses traction-motor fields.	
1,2, 3,4	Traction Motors	Converts electrical power into mechanical power to move locomotive.	
100	Battery Switch	Disconnects battery.	

SYMBOL	NAME	FUNCTION	DATA
101	Throttle-Control Switch	Energizes traction control equipment.	
102	Ammeter Shunt	Carries current for ammeter (BA).	
103	Fuse	Protects auxiliary-generator armature.	80 amps
104	Fuse	Protects auxiliary-generator field.	10 amps
105	Fuse	Protects battery against overload.	110 amps
106A, 106B	Fld. Shunt Resis.	Reduces traction-motor field strength when connected by M1 and M2.	
107A, 107B	Hdlt. Resis.	Controls headlight voltage.	
108	Grd.Relay Switch	Cuts out ground relay.	

SYMBOL	NAME	FUNCTION	DATA
110	Throttle Field Switch	Gives "soft starting" for spotting (SU only).	
111	Ammeter Shunt	Shunt for 112 (standard on road switchers).	
112	Traction-Motor Ammeter	Indicates load on traction motors (standard on road switchers).	
113	Governor Solenoid	Shuts down diesel engine.	
114	Resis.for 113	Limits current in governor solenoid coil.	
115	Eng.Lube-Oil Press. Switch	Shuts down diesel engine when lubricating-oil pressure drops to 20 pounds or less.	
116	Heater Fan Motor	Circulates warm air in locomotive cab.	

SYMBOL	NAME	FUNCTION	DATA
117	Control Switch	Energizes locomotive control circuits.	
117	Engine-Start Switch	Starts the diesel engine.	
117	Fuel-Pump Switch	Energizes fuel-pump motor and governor solenoid.	
117	Headlight Switch	Controls headlight on front and rear of locomotive.	
117	Gage Light		
117	Dome Light		
117	Eng. Room	Switches control specified lighting circuits.	
117	Number		
117	Marker		
118	Wheel Slip Buzzer	Sounds when wheels slip.	

SYMBOL	NAME	FUNCTION	DATA
121	Train-Line Resistor Panel	Prevents excessive current in control circuit train line in MU operation.	
122	Sander Foot Switch	Provides foot control of sanding (MU).	
123	Sander Magnet Valve	Opens air line to sander relay valve which controls air to sand trap (MU).	
124	Series Holding Switch	Holds traction motors in series connection (MU).	
125	Comprt. Light Switch	Controls compartment lights.	
126	Fuse	Protects control compartment lighting circuit.	

FUSES IN 17HP4L3 CONTROL STATION IN CAB

CIRCUIT	AMP
Engine Starting	10
Control	10
Fuel-Pump Motor	10
Front Headlight, Dim	10
Front Headlight, Bright	None
Rear Headlight, Dim	10
Rear Headlight, Bright	None
Far Headlight, Dim (MU)	10
Far Headlight, Bright (MU)	None
Gage Lights	10
Dome Light	10
Engine Room Lights	10
Number Lights	10
Marker Lights	10
Heater	10

EFFECT OF BLOWN FUSES - WHEN STARTING UP

Condition	Fuses Involved
Diesel engine cannot be cranked.	105, control switch fuse and start switch fuse.
Fuel-pump motor will not run.	105, fuel-pump switch fuse.

LOCOMOTIVE IN OPERATION

Auxiliary generator not charging battery.	
Battery ammeter shows discharge.	103 (80 amp) and 104 (10 amp)
Battery will lose its charge.	
Battery ammeter reads zero.	
No control voltage.	105 (110 amp).

Condition	Fuses Involved
Traction-motor contactors opening.	
Battery charge stops.	Control fuse (10 amp).
Diesel engine loses its load.	
Fuel pump stops.	
Governor solenoid stops engine.	Fuel-pump fuse (10 amp).

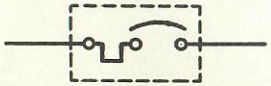
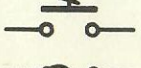
WIRING DIAGRAM SYMBOLS

IMPORTANT: When reading ALCO-GE wiring diagrams:

1. Devices are shown in de-energized position.

2. Reverser contacts and interlocks are set up for forward operation.

3. Circuits and devices are set up for motoring.

SYMBOL	DEVICE
	Finger type contacts - contactor, relays and interlocks.
	Bridging type contacts - contactors, relays and interlocks.
	Reverser main contacts.
	Resistor.
	Rheostat or Potentiometer.
	Operating coil of a device.
	Field coil (motor or generator).
	Lamp bulb.
	Circuit breakers.
	Push-button switch.
	Push-button switch, spring return.
	Fuse.

SEQUENCE TABLE

CONTACTOR SEQUENCE TABLE

STEPS	CONTACTORS									
	S	SP1	SP2	EF	GF	CR1	GSI	GS2	MI	M2
Starting							●	●		
Idling										
Series	●			●	●					
T1	●			●	●	●				
T2	●			●		●				
T3	●	●		●		●				
T4		●		●		●				
T5		●	●	●		●				
Ser - Par		●	●	●	●	●				
Reduced Field		●	●	●	●	●			●	●

CONTACTOR B IS CONTROLLED BY RC RELAY

660-HP and 1000-HP Switching Locomotive
Single-Unit Control

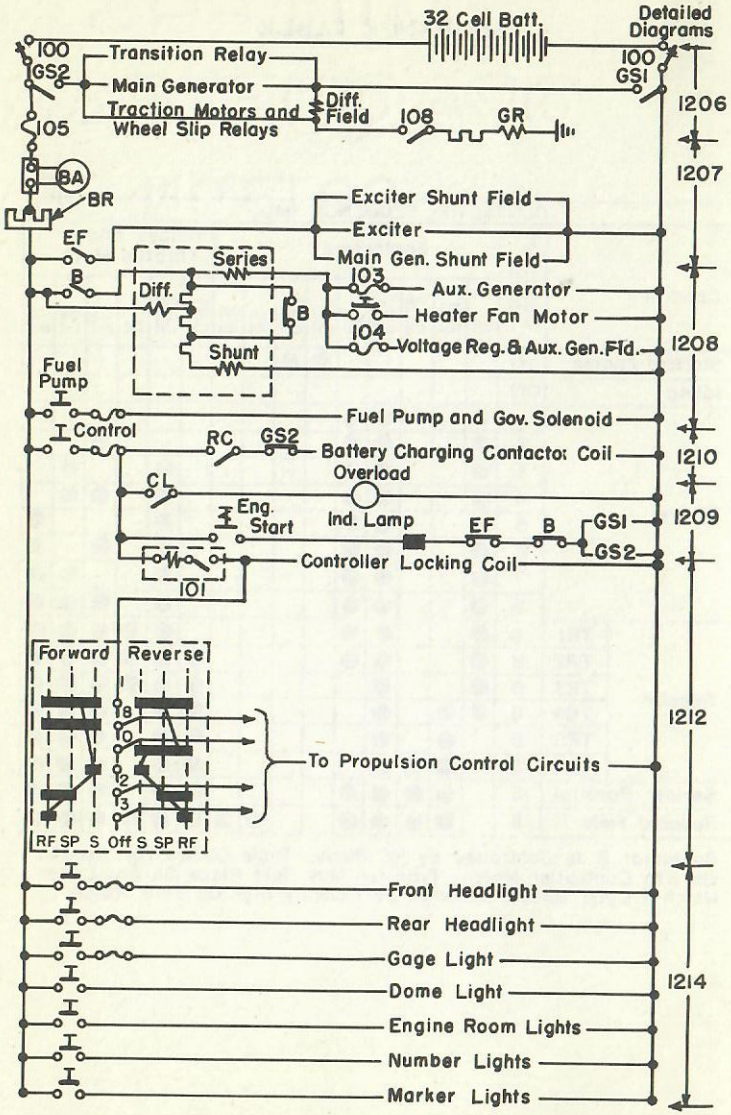
SEQUENCE TABLE

CONTACTOR SEQUENCE (MU)

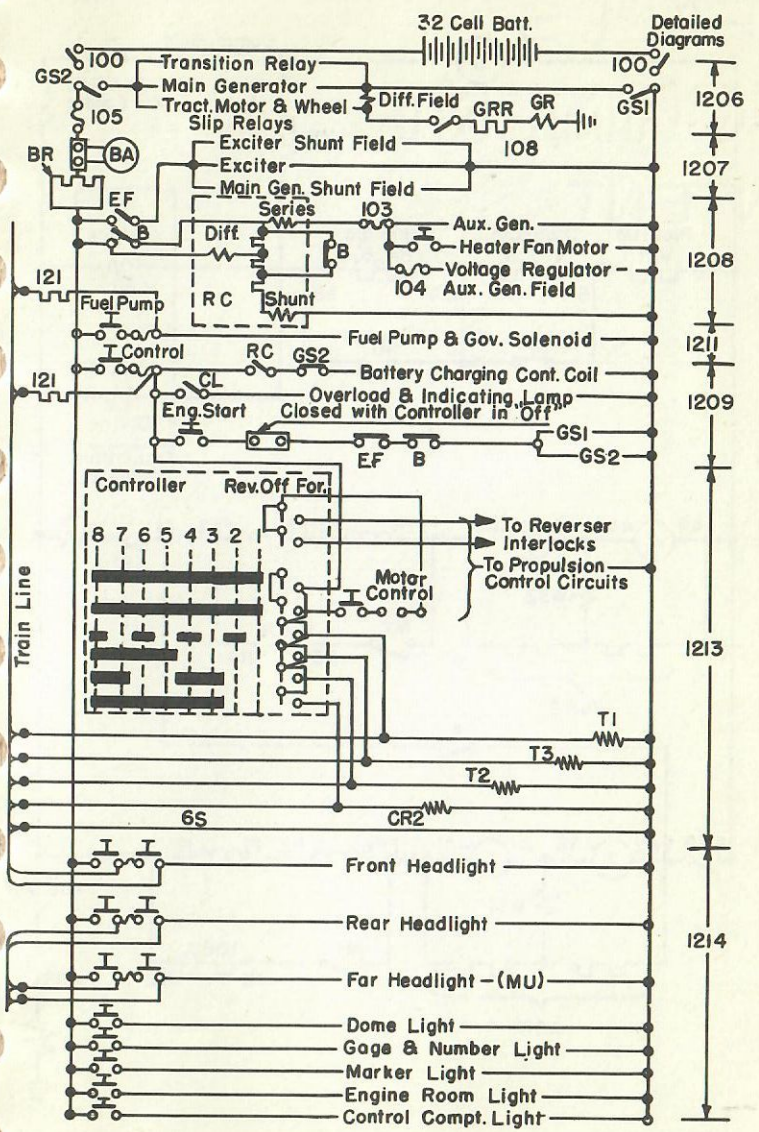
Condition		Controller Notch	Contactors									Relays And Throttle Mech.					
			S	SP1	SP2	EF	GF	GSI	GS2	MI	M2	CR1	CR2	V	T1	T2	T3
Starting Engine		Off						●	●								
Idling		Off															
Series		1	●			●	●										
		2	●			●	●								●		
		3	●			●	●						●			●	
		4	●			●	●						●		●	●	
		5	●			●	●						●				●
		6	●			●	●						●		●		●
		7	●			●	●						●			●	●
		8	●			●	●						●		●	●	●
Transfer	TR1	8	●			●	●						●	●	●	●	●
	TR2	8	●			●	●					●	●	●	●	●	●
	TR3	8	●			●						●	●	●	●	●	●
	TR4	8	●	●		●						●	●		●	●	●
	TR5	8		●		●						●	●		●	●	●
	TR6	8		●	●	●						●	●		●	●	●
Series - Parallel		8		●	●	●	●					●	●		●	●	●
Reduced Field		8		●	●	●	●			●	●	●	●	●	●	●	●

Contactor B Is Controlled By RC Relay. Table Shown For Transfer On 8th Controller Notch. Transfer May Take Place On Any Lower Notch If Loco Speed Becomes Sufficiently High On That Notch.

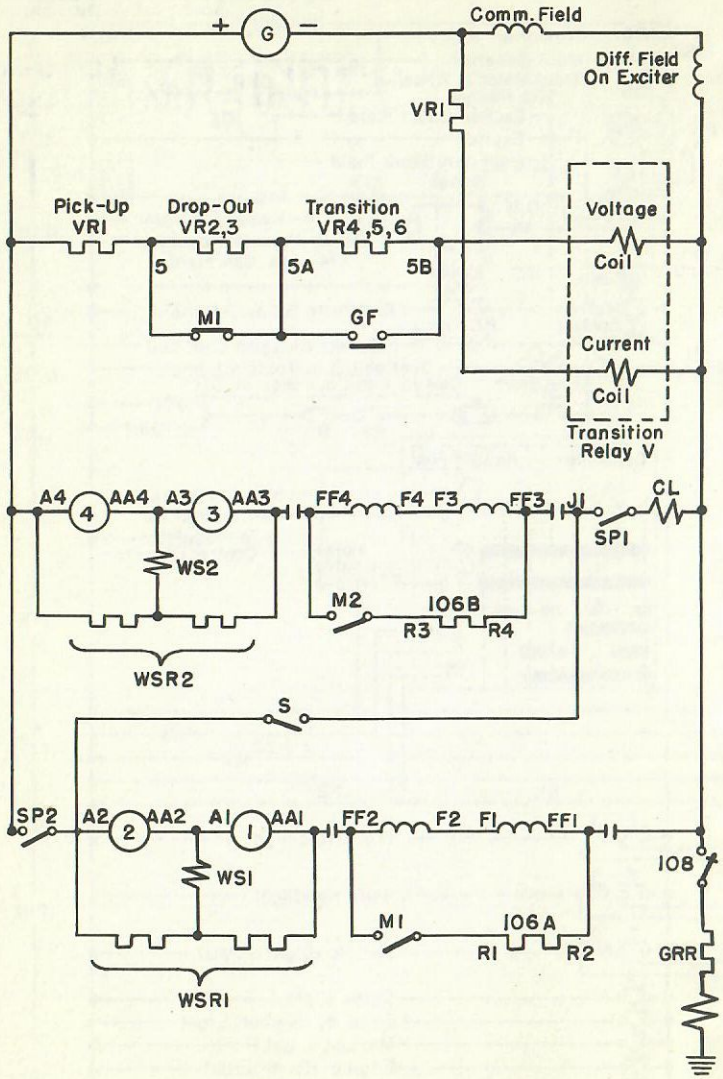
1000-HP Switching and Road-Switching
Locomotives
Multiple-Unit Operation



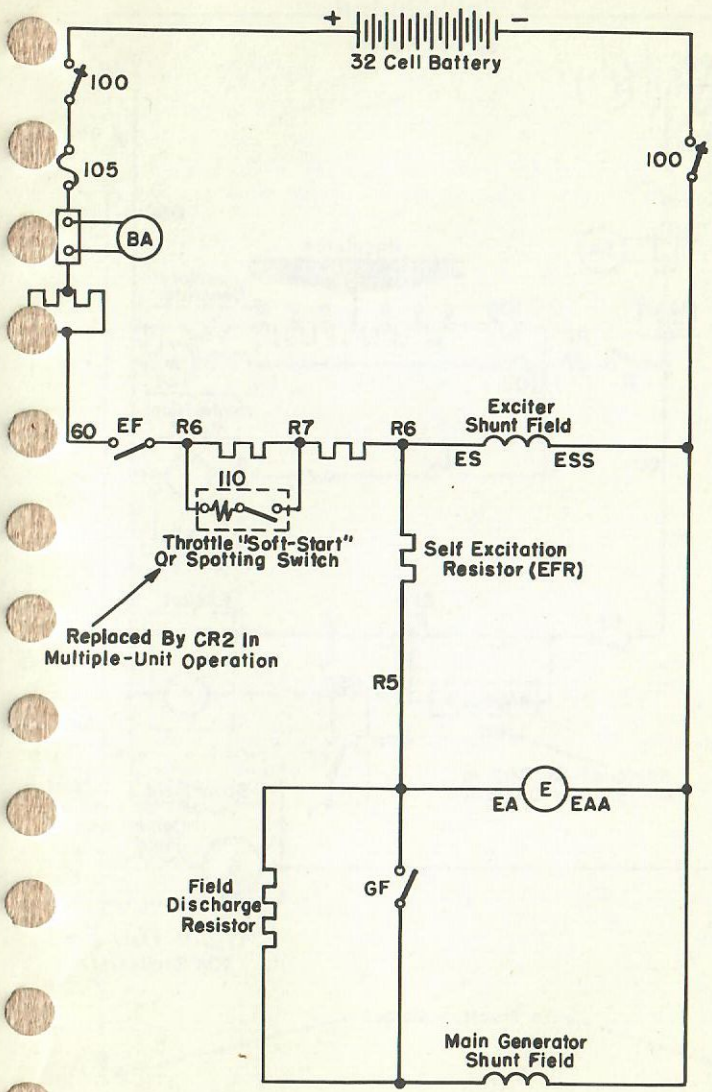
Master Schematic Connection Diagram
660-1000 HP - Single-Unit Control



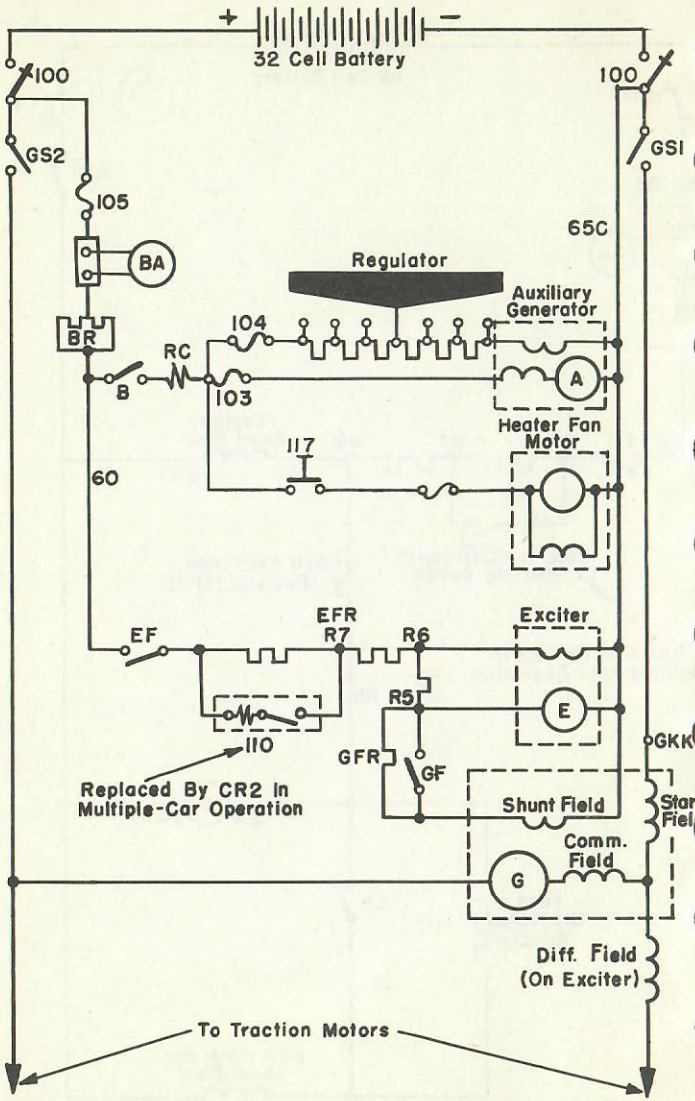
Master Schematic Connection Diagram
660-1000 HP - Multiple-Unit Control



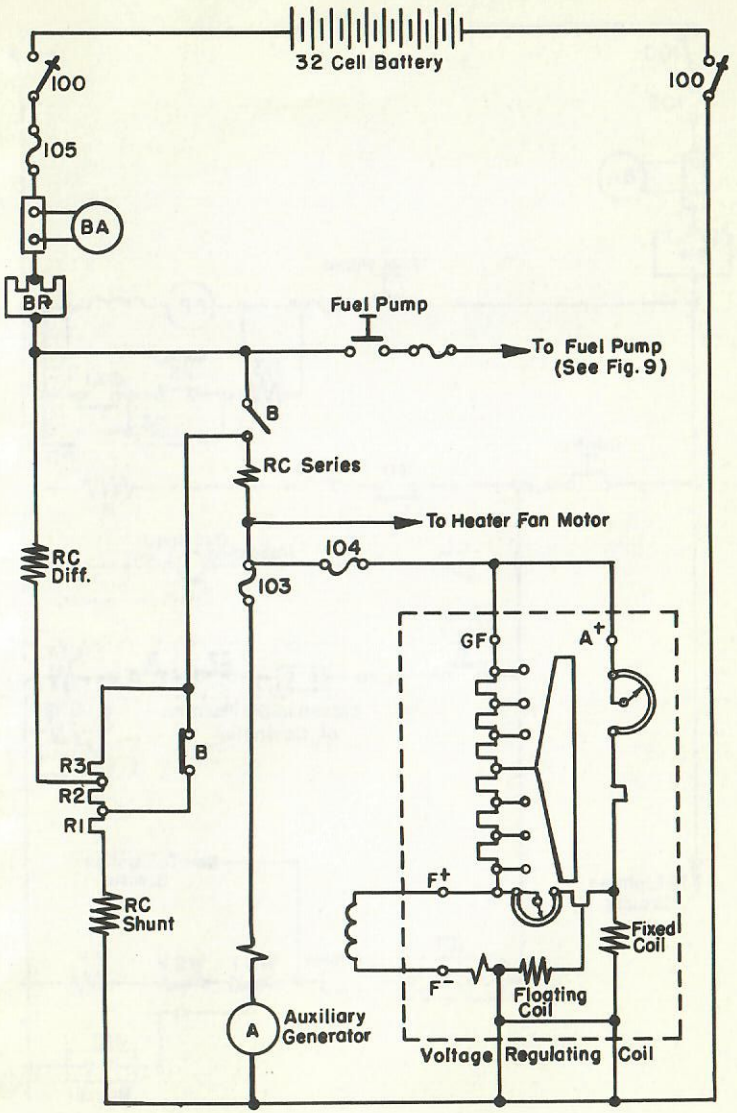
Main Power Circuit with Transition, Wheel-Slip, and Ground Relays



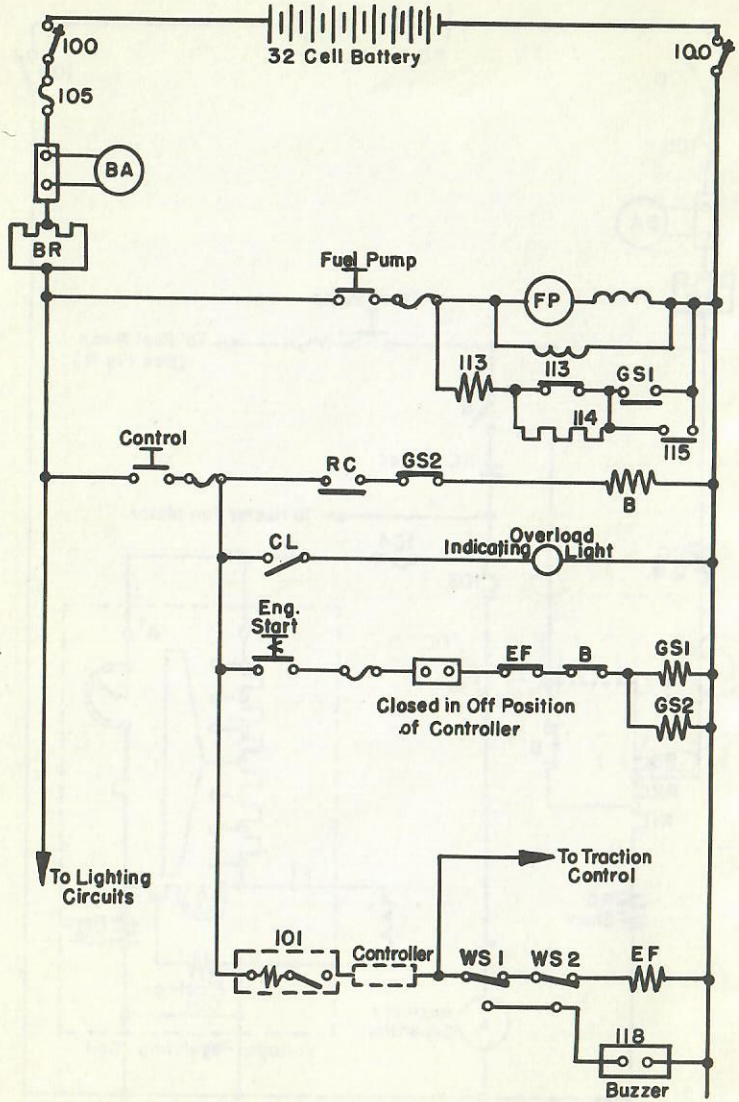
Generator Excitation Circuits



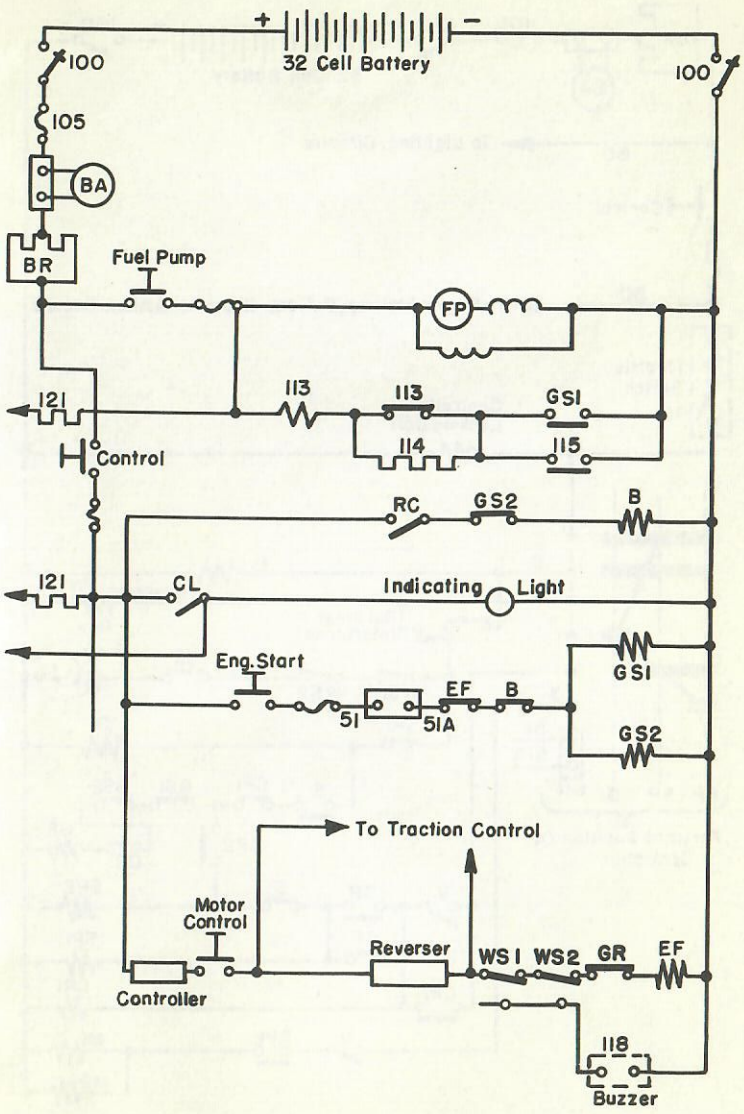
Power and Cranking Circuits



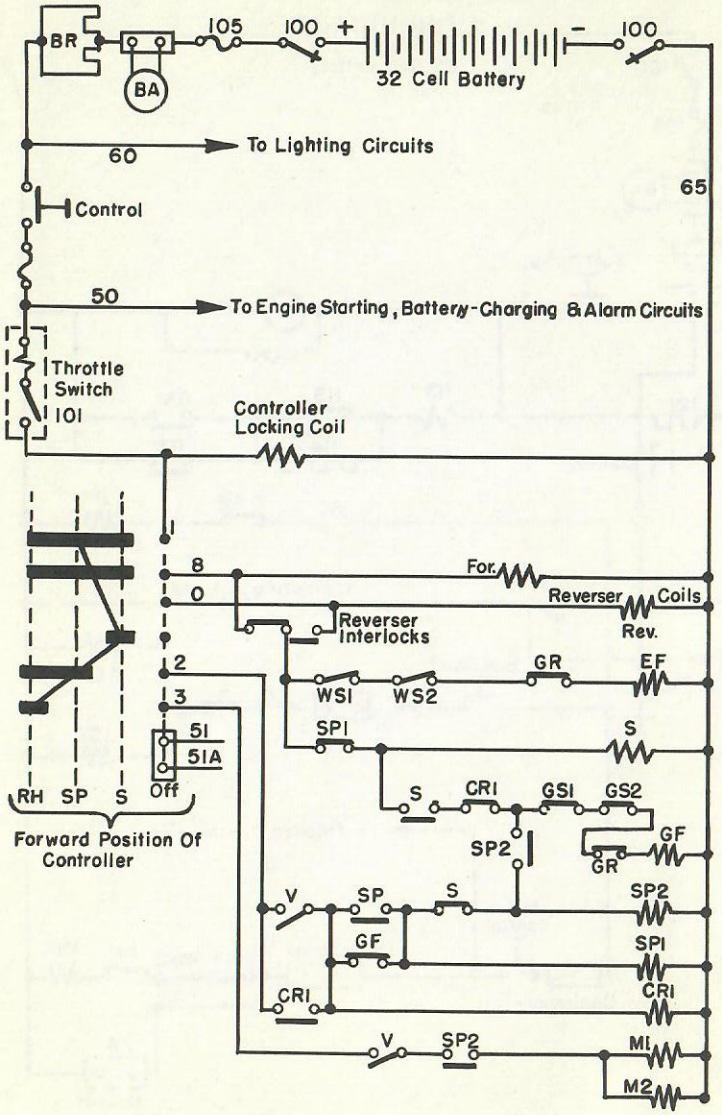
Auxiliary Generator, Voltage-Regulating Relay and Battery-Charging Circuits



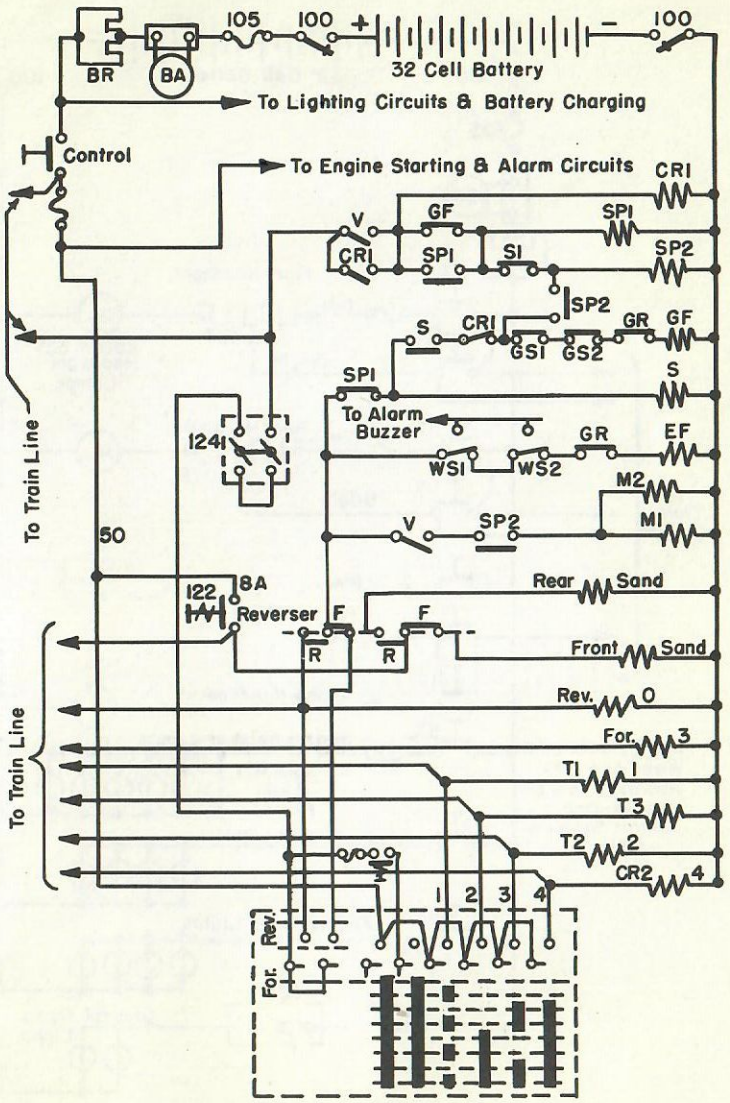
Engine-Starting, Control and Alarm Circuits
Single-Unit Control



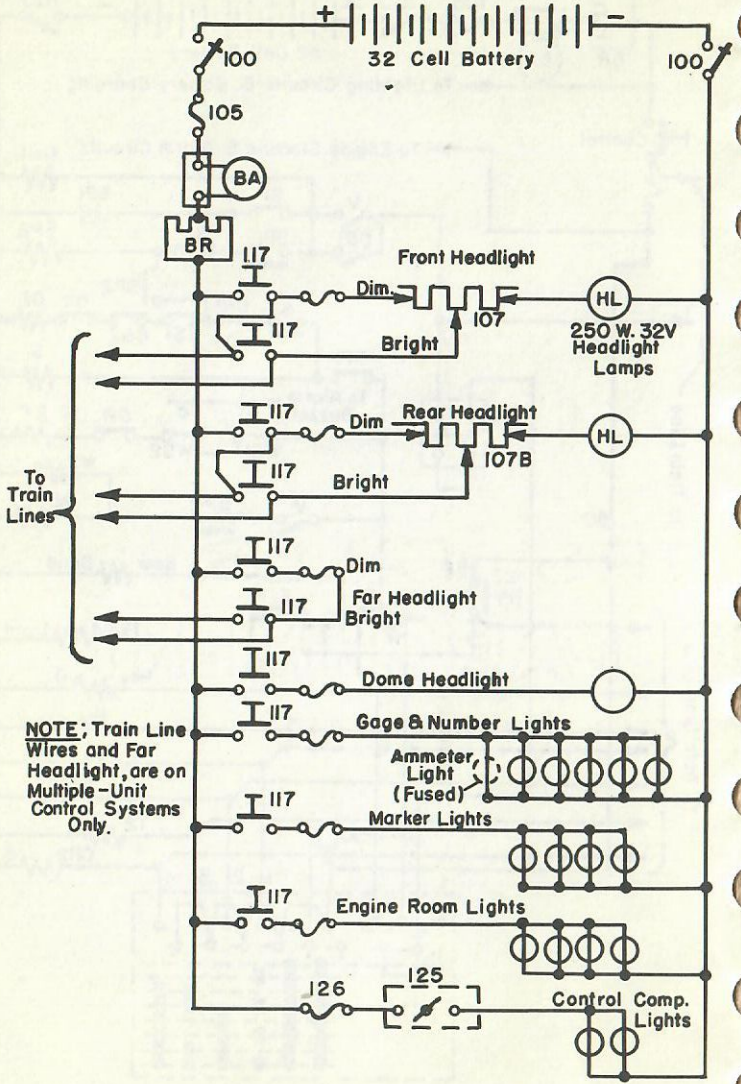
Engine-Starting, Control and Alarm Circuits



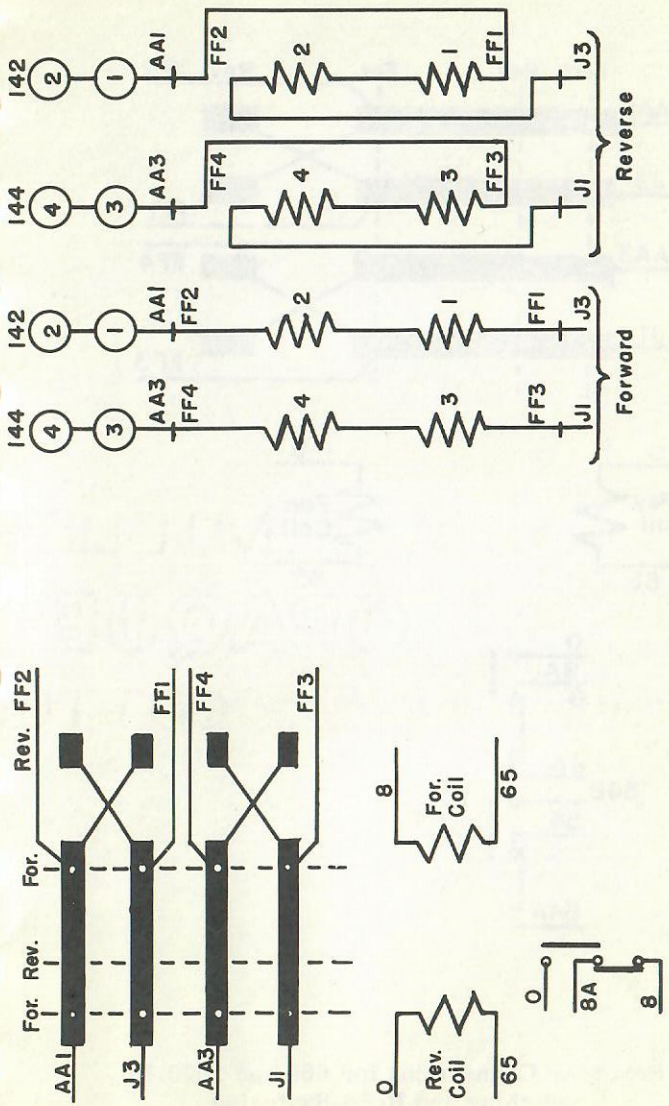
Traction Control Circuits (SU)



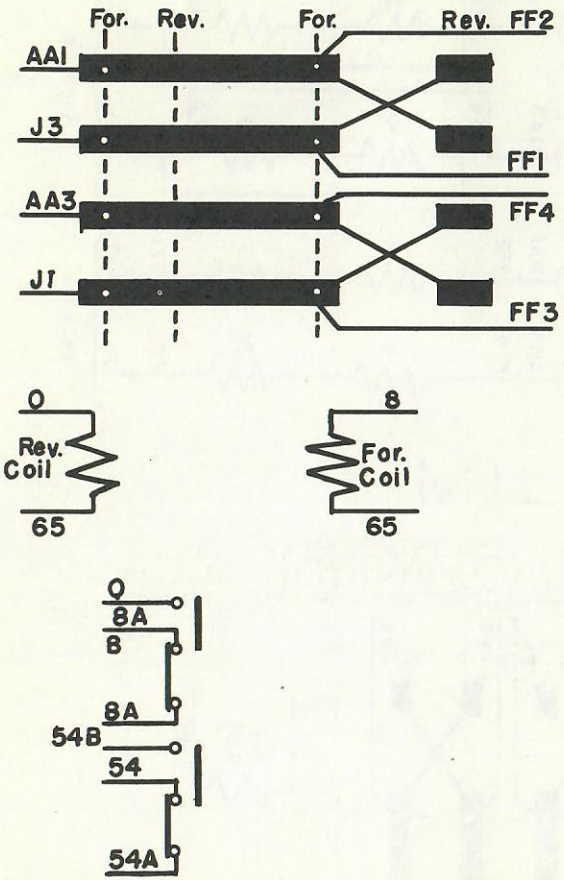
Traction Control Circuits (MU)



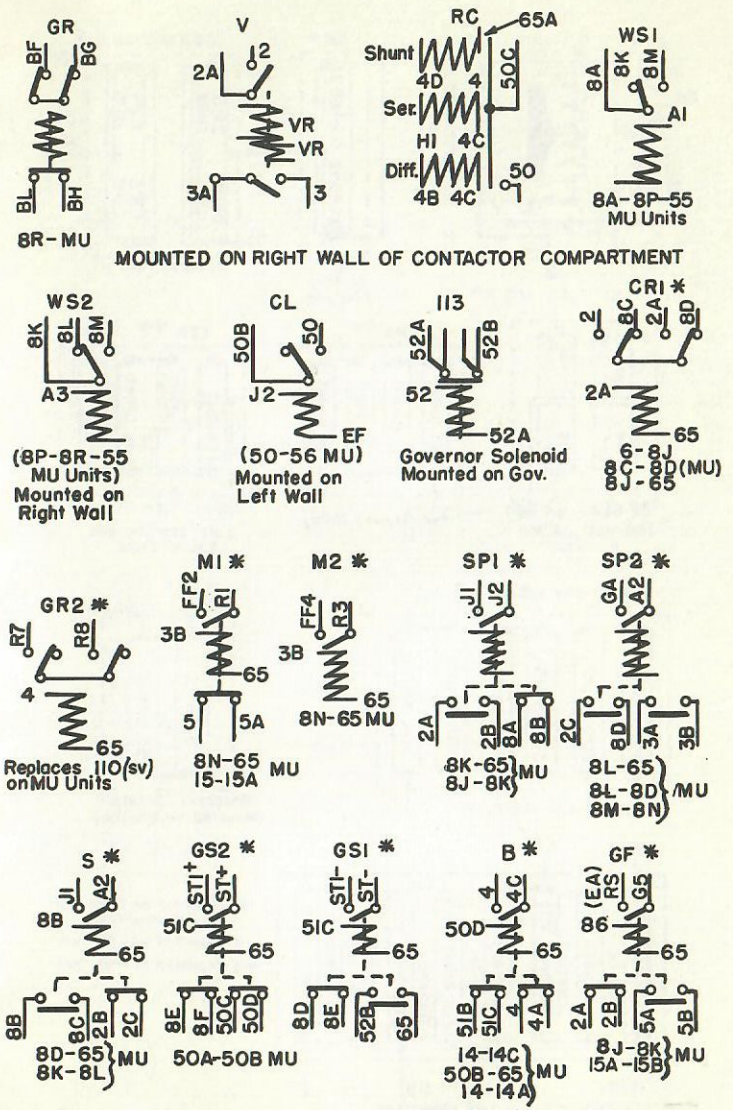
Lighting and Headlight Circuits



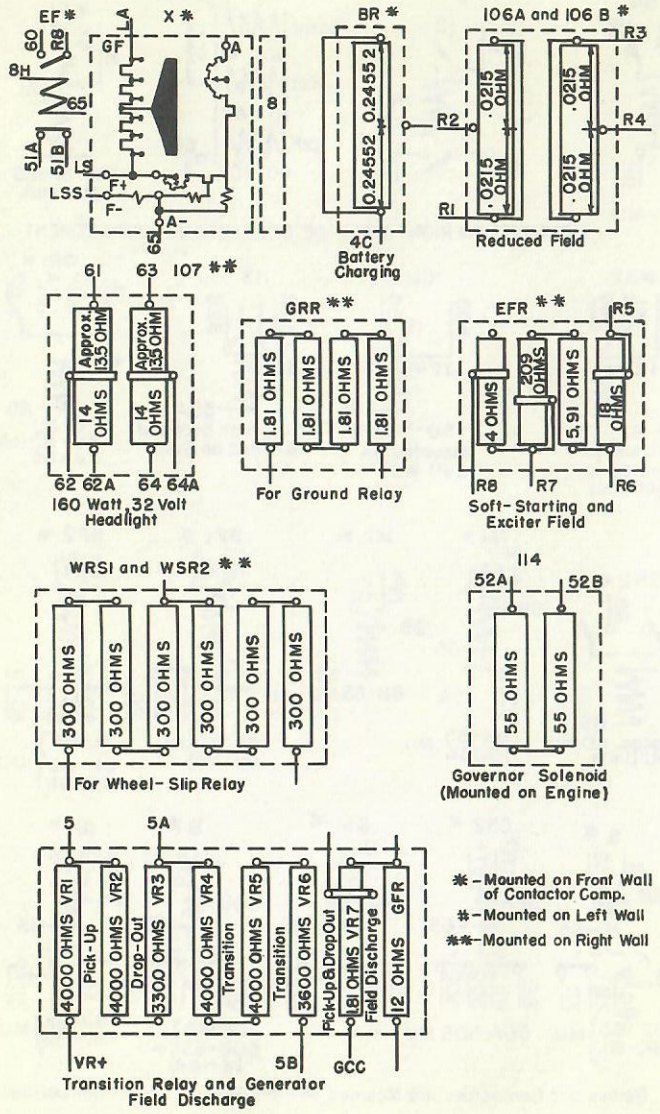
Reverser Connections for 660 and 1000-Hp Switching and Road-Switching Single-Unit Operation Locomotives



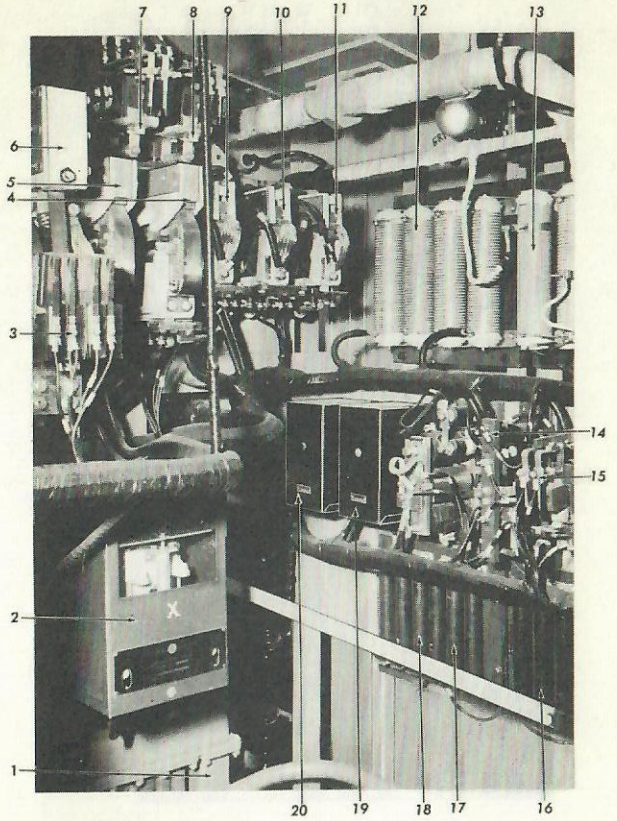
Reverser Connections for 660 and 1000-Hp Switching and Road-Switching Multiple-Unit Operation Locomotives



Coil and Contact Positions on Relays and Contactors

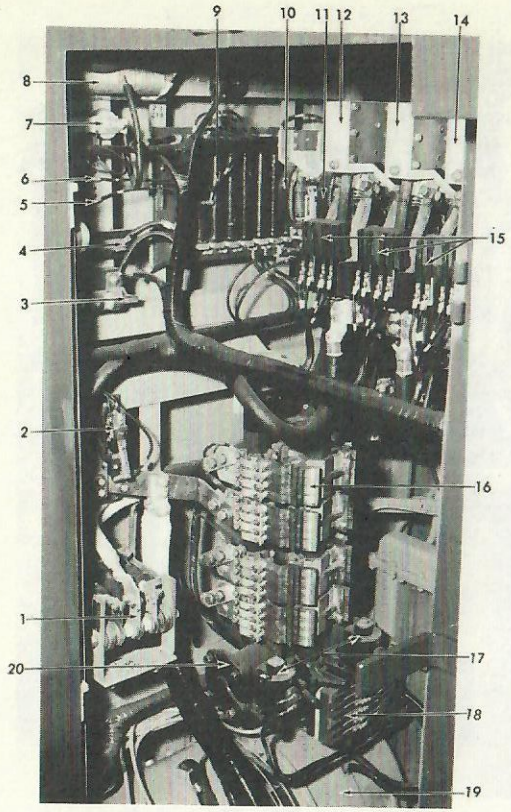


Coil, Contact Positions and Resistor Connections



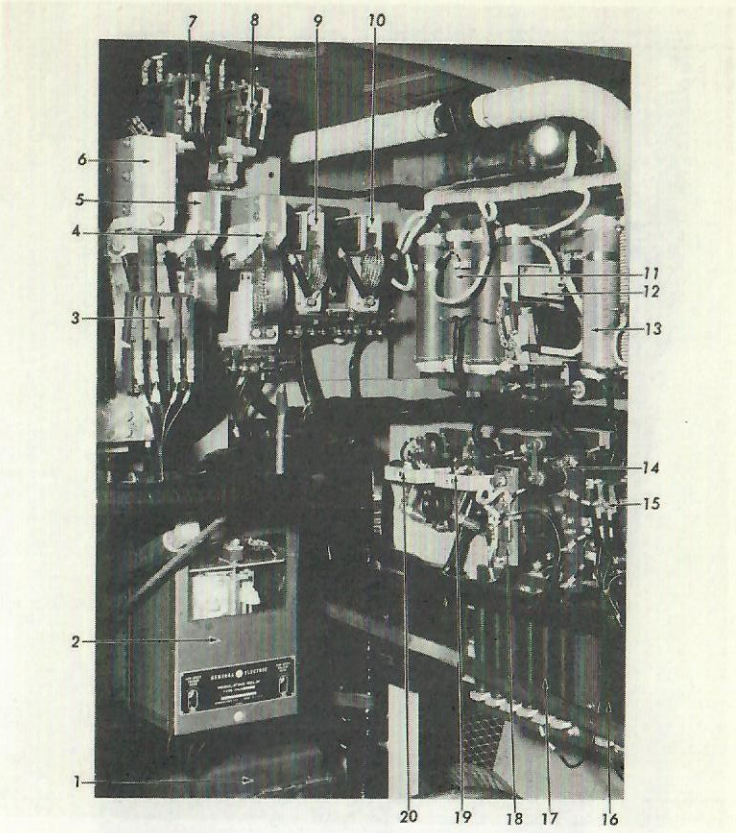
1. Intercooler for air compressor
2. Voltage-regulating relay
3. Interlock on contactor SP2
4. Engine-cranking contactor GS2
5. Engine-cranking contactor GS1
6. Series-parallel motor contactor SP2
7. Control relay CR1
8. Control relays CR2
9. Battery-charging contactor B
10. Generator field contactor GF
11. Exciter-field contactor EF
12. Ground-relay resistor GFR
13. Exciter-field resistor EFR
14. Transfer relay V
15. Ground relay GR
16. Wheel-slip resistor WSR1
17. Wheel-slip resistor WSR2
18. Reverse-current relay RC
19. Wheel-slip relay WS1
20. Wheel-slip relay WS2

1000-Hp Switcher
Right Side of Contactor Compartment
M-U Control



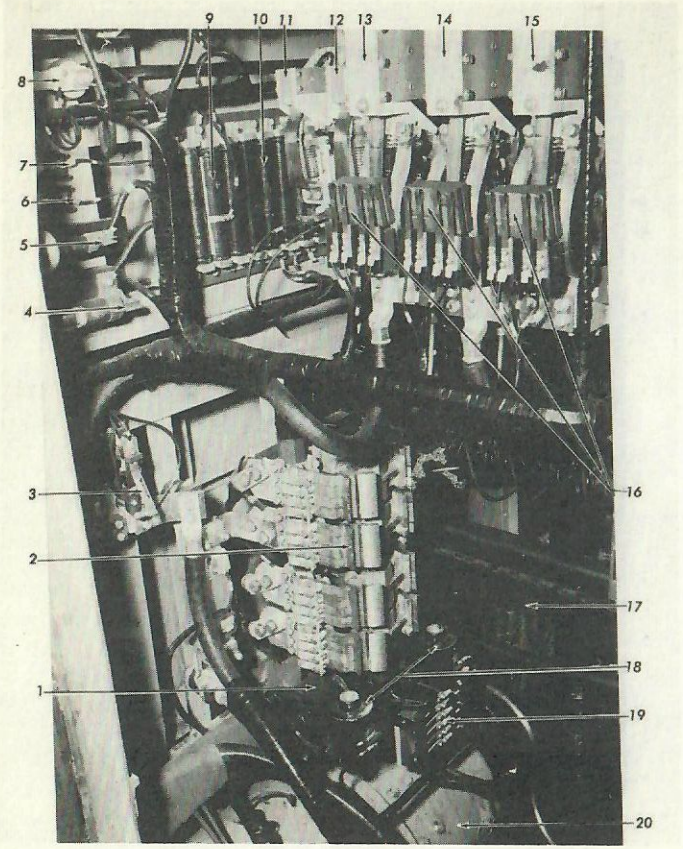
1. Field shunt resistor, 106A and 106B
2. Current-limit relay CL
3. Battery fuse (110 amp) 105
4. Auxiliary-generator fuse (80 amp) 103
5. Auxiliary-generator field fuse (10 amp) 104
6. Contactor compartment light fuse (10 amp)
7. Battery shunt 102
8. Battery-charging resistor BR
9. Control resistors. Adjustable resistors for VR1 to VR7 transition relay.
10. Field-shunting contactor M1
11. Field-shunting contactor M2
12. Motor contactor SP1
13. Motor contactor S
14. Motor contactor SP2
15. Interlocks on motor contactors SP1, S, SP2
16. Reverser
17. Reverser magnet valves (two)
18. Reverser interlock
19. GMG-139 Exciter auxiliary generator set
20. Reverser air engine
21. Generator field discharge resistor GFR

1000-Hp Switcher
Left Side of Contactor Compartment
M-U Control



1. Intercooler for air compressor
2. Voltage-regulating relay
3. Interlock on contactor SP2
4. Engine-cranking contactor GS2
5. Engine-cranking contactor GS1
6. Series-parallel motor contactor SP2
7. Control relay CR1
8. Control relay CR2
9. Battery-charging contactor B
10. Generator-field contactor GF
11. Headlight resistors
12. Exciter-field contactor EF
13. Exciter-field resistor EFR
14. Transfer relay V
15. Ground relay GR
16. Wheel-slip resistor WSR1
17. Wheel-slip resistor WSR2
18. Reverse-current relay RC
19. Wheel-slip relay WS1
20. Wheel-slip relay WS2

1000-Hp Road Switcher
Right Side of Contactor Compartment
M-U Control



1. Reverser air engine
2. Reverser
3. Current-limit relay CL
4. Battery fuse (110 amp) 105
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9. Generator field discharge resistor GFR
10. Control Resistors: Adjustable resistors for VR1 to VR7 transition relay.
11. Field-shunting contactors M1
12. Field-shunting contactors M2
13. Motor contactor SP1
14. Motor contactor S
15. Motor contactor SP2
16. Interlocks on motor contactors SP1, S, SP2
17. Air-compressor intercooler
18. Reverser magnet valves
19. Reverser interlock
20. GMG-139 exciter auxiliary generator set

1000-Hp Road Switcher
Left Side of Contactor Compartment
M-U Control

TESTS ON CONTROL DEVICES

Follow instructions carefully to avoid danger to oneself and damage to the equipment. MAKE ALL TESTS WITH ENGINE SHUT DOWN AND MAIN BATTERY SWITCH (100) CLOSED.

	DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
1.	B	BATTERY-CHARGING CONTACTOR
		a. IMPORTANT - Remove fuse 103.
		b. Close control push-button switch.
		c. Close RC relay contacts by hand.
		1. Contact B should close.
		d. Replace fuse 103 when test is completed.
2.	Buzzer (118) WS1-WS2	WHEEL-SLIP RELAYS AND BUZZER
		a. Close control push-button switch (also motor control switch on MU).
		b. Turn selector handle to FORWARD or REVERSE.
		c. Open throttle past IDLING.
		d. Close WS1 or WS2 by hand.
		1. Buzzer will sound.

DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
3. Overload Indicating Lamp and CL	OVERLOAD RELAY AND LAMP a. Close control push-button switch. b. Close CL relay by hand. 1. Lamp should light.
4. GS1-GS2	ENGINE-STARTING CONTACTORS a. Insert fiber strips or thin wood wedges between main contacts, so they cannot touch. b. Turn selector to OFF position. (Throttle on MU). c. Close control push-button switch. d. Close engine-start switch. 1. GS1 and GS2 contactors should close.
5. 113,115	GOVERNOR SOLENOID a. Close fuel-pump push-button switch. b. Close engine lube-oil pressure switch 115. 1. Governor solenoid should pull down.

DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
6. Fuel Pump	FUEL-PUMP MOTOR a. Close fuel-pump push-button switch. 1. Fuel-pump motor should start and run.
7. 101	THROTTLE CONTROL SWITCH (SU Only) a. See test on CONTROLLER LOCKING COIL.
8. Controller Locking Coil	a. Turn selector handle to OFF position. b. Close control push-button switch. c. Open throttle part way. 1. If device is operating, selector handle cannot be moved from its OFF position. 2. If controller is in any running position when the throttle is opened, it may be turned to any other running position for the same direction of movement, or to OFF, but not out of OFF position until the throttle is closed again.

DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
9.	REVERSER
	a. Close control push-button switch.
	b. Turn selector handle to FORWARD or REVERSE.
	c. Open throttle past idling.
	1. Reverser drum should turn to its proper position.
10. EF, S, GF, CR1, SP1, SP2,	CONTACTOR AND RELAY SEQUENCES (SU Operation)
	a. Series Transition.
	1. Close control push-button switch.
	2. Turn selector to its forward reduced field position.
	3. Open throttle past idling.
	a. EF, S, GF should close in order named.
	b. Series-Parallel Transition.
	1. Close V relay momentarily by hand.
	a. CR1 relay and SP1, SP2 contactors should close, and GF contactor should open.

DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
10. (Cont'd)	b. S contactor should open.
	c. GF contactor should then close.
M1, M2	c. Reduced-Field Transition (Field Shunting).
	1. Close V relay by hand.
	a. M1 and M2 contactors should close.
	2. Release V relay.
	a. M1 and M2 contactors should open.
GR, EF, GF	d. Ground Protection.
	1. Close GR Relay by hand until it latches.
	a. EF, GF contactors should open.
	2. Unlatch and reset GR relay.
	a. EF and GF contactors should close.
10A. EF, S, GF, CR1, SP1, SP2,	CONTACTOR AND RELAY SEQUENCE (MU Operation)
	a. Series Transition.
	1. Close control push-button switch.

DEVICE SYMBOL	DEVICE NAME AND OPERATING TEST
10A. (Cont'd)	2. Close motor control push-button switch.
	3. Selector in FORWARD or REVERSE.
	4. Open throttle past IDLING.
	a. EF, S and GF should close in order named.
	b. Series-Parallel Transition.
	1. Close control push-button switch.
	2. Close motor control push-button switch.
	3. Close series-holding switch 124.
	4. Close V relay momentarily by hand.
	a. CR1 relay and SP1, SP2 contactors should close and GF contactor should open.
	b. S contactor should open.
	c. GF contactor should then close.
M1, M2	c. Reduced-Field Transition (Field Shunting)
	Same as for SU operation.
GR,EF,GF	d. Ground Protection.
	Same as for SU operation.

Condition	Manual Operation	Normal Operation of Electric Devices	Result if Device Does Not Operate
Locomotive dead	Battery switch open	All circuits de-energized.	Danger of short circuit.
Opening up locomotive	Battery switch closed	Control switches energized.	All lights and control will be inoperative.
	Throttle in IDLE position	Controls amount of fuel oil going to diesel engine.	Engine will overspeed on starting.
	Reverser in OFF position	Prevents excitation of exciter and traction generator.	Locomotive would start moving prematurely.
Starting diesel engine	Fuel-pump push button switch closed	Fuel-pump motor starts.	Diesel engine will not receive fuel.
		All fuel-oil valves must be open.	Diesel engine will not receive fuel.
	Engine-start push-button switch held closed.	Control switch closed.	Contactors will not close.
		GS1 contactor closed.	Diesel engine will not turn over.
		GS2 contactor closed.	" " " "
		Governor solenoid down.	Diesel engine will not fire.
		Battery charge must be up.	Diesel engine will not turn over.

Condition	Manual Operation	Normal Operation of Electric Devices	Result if Device Does Not Operate
Idling, battery charging and air pumping	Throttle part way open	Fuel pump running. Governor solenoid down. RC relay contacts closed. B contactor closed. X voltage-regulating relay contacts closed.	Diesel engine will stop. " " " " Ammeter will show discharge. " " " " " " " "
Pumping air above IDLING speed	Throttle opened past IDLING	Selector in OFF position. Fuel-pump motor running. Governor solenoid down. RC relay closed. B contactor closed.	Locomotive moves when air pressure builds up. Diesel engine will stop. " " " " Ammeter will show discharge. " " " "
Locomotive moving in series (low speed)	Throttle opened past IDLING	Selector in series, series parallel or reduced field. Fuel-pump motor running. Governor solenoid down. RC relay closed. B contactor closed.	Locomotive will not move. Diesel engine will stop. " " " " Ammeter will show discharge. " " " "

Condition	Manual Operation	Normal Operation of Electric Devices	Result if Device Does not Operate
(Cont'd)		Reverser shifts if set for opposite direction.	Locomotive will not move.
		EF contactor closed.	Diesel engine will develop very little power.
		S contactor closed. GF contactor closed.	Locomotive will not move. Diesel engine will develop very little power.
		Motor control switch closed. CR2 relay closed (above 2nd notch.	Locomotive will not move. Diesel engine will not develop full horsepower.
		Series holding switch 124 closed (MU only).	Transition will not take place.
Moving locomotive in series-parallel (intermediate speed)	Throttle opened past IDLING	Selector in series-parallel or reduced field. Fuel-pump motor running. Governor solenoid down. RC relay closed. B contactor closed.	Locomotive will not move. Diesel engine will stop. " " " " Ammeter will show discharge. " " " "

Condition	Manual Operation	Normal Operation of Electric Devices	Result if Device Does not Operate
	(Cont'd)	Reverser in FOR. or REV.	Locomotive will not move.
		EF contactor closed.	Diesel engine will develop very little horsepower.
		Switch 124 closed (MU only).	Transition will not take place.
		Motor control switch closed.	Locomotive will not move.
		V relay closed momentarily.	Trac.motor will stay in series.
		CR1 relay closed.	,, ,, ,, ,, ,, ,,
		CR2 relay closed (MU only).	Diesel engine will not develop full horsepower.
		SP1 contactor closed.	Trac.motor will stay in series.
		SP2 contactor closed.	D-E will develop very little power.
		GF contactor closed.	,, ,, ,, ,, ,,
Moving locomotive in reduced field (high speed)	Throttle opened enough for desired speed	Selector in reduced field.	Trac.motor stays in series-parallel.
		Fuel-pump motor running.	Diesel engine will stop.
		Governor solenoid down.	,, ,, ,, ,,
		RC relay closed.	Ammeter will show discharge.
		B contactor closed.	,, ,, ,, ,,
		Reverser in FOR. or REV.	Locomotive will not move.
		EF contactor closed.	D-E develops very little power.
		Switch 124 closed (MU only).	Transition will not take place.

Condition	Manual Operation	Normal Operation of Electric Devices	Result if Device Does Not Operate
	(Cont'd)	Motor control switch closed.	Locomotive will not move.
		CR1 relay closed.	Trac.motors stay in SERIES.
		CR2 relay closed.	D-E will not develop full HP.
		SP1 contactor closed.	Trac.motors stay in SERIES.
		SP2 contactor closed.	D-E develops very little power.
		GF contactor closed.	,, ,, ,, ,, ,,
		V relay closed.	Trac. motors will stay in series-parallel.
		M1 contactor closed.	Trac. motors will stay in series-parallel.
		M2 contactor closed.	Trac. motors will stay in series-parallel.

Device Symbol	Name	Contacts Necessary to Operate
B	Battery Charging Contactor	Battery switch 100 closed. Battery fuse 105 good. Control switch closed, fuse good. RC relay contacts closed. CAUTION: Do not close contacts manually. GS2 interlocks closed, GS2 contactor open.
CL	Current Overload Relay	Operates to close its contacts when the current in No. 3 and 4 traction motors is high in the series-parallel and reduced-field position. Contactors SP1 and SP2 closed. NOTE: Relay not operative in series position.
CR1	Control Relay	Selector in series-parallel or reduced-field position. V relay contacts closed momentarily. Series holding switch 124 in "ON" position (MU only). Motor-control switch in closed position (MU only). NOTE: CR1 stays in through its own contacts after V contacts open.
CR2	"Soft-Start" Relay	Relay closes when throttle is in 3rd notch or higher, bypassing resistance R7 and R8. Corresponds to switch 110 in single-unit operation.
EF	Exciter-Field Contactor	Control switch closed, fuse good. Selector handle in any but OFF position.

Device Symbol	Name	Contacts Necessary to Operate
EF (Cont'd)	Exciter-Field Contactor	Throttle open past idle. Reverser interlocks closed with WS1 and WS2 relay open. GR interlock closed, GR relay open. 117 motor control switch closed (MU).
GF	Main Generator Field Contactor	WITH TRACTION MOTORS IN SERIES Control switch closed, fuse good. Reverser interlocks closed in proper direction. Selector handle in any but "OFF" position. Throttle open past idle. 117 motor control switch closed (MU). S interlocks closed, S contactor closed. CR1 contacts closed, CR1 relay open. GS1 interlocks closed, GS1 contactor open. GS2 interlocks closed, GS2 contactor open. GR contacts closed, GR relay open. WITH MOTORS IN SERIES-PARALLEL OR REDUCED FIELD Control switch closed, fuse good. Reverse interlocks closed in proper direction. Selector handle in any but OFF position.

Device Symbol	Name	Contacts Necessary to Operate
GF (Cont'd)	Main Generator Field Contactor	Throttle open past IDLE. 117 motor control switch closed (MU). SP2 interlocks closed, SP2 contactor closed. GS1 interlocks closed, GS1 contactor open. GS2 interlocks closed, GS2 contactor open. GR contacts closed, GR relay open.
113	Governor Solenoid	Fuel-pump switch closed, fuse good. Governor-solenoid auxiliary contacts closed with solenoid up. NOTE: When solenoid pulls down, the auxiliary contacts open to insert a holding resistance in series with solenoid coil. GS1 interlocks closed with GS1 contactor closed or 115 engine lubricating-oil pressure switch contacts closed with oil pressure normal.
GR	Ground Relay	Ground switch 108 closed. Normally de-energized with its contacts closed. Ground current pulls in relay armature, opens its contacts and breaks the GF and EF contactor circuits. Relay returns to normal position when latch is tripped by hand.

Device Symbol	Name	Contacts Necessary to Operate
GS1 GS2	Engine-Cranking Contactors	Battery switch 100 closed. Battery fuse 105 good. Control switch closed, fuse good. Engine-start switch closed, fuse good. Selector in OFF position. EF interlocks closed, EF contactor open. B interlocks closed, B contactor open.
M1, M2	Traction-Motor Field Shunting Contactors	Selector in reduced-field position (SU). Control switch closed, fuse good. Reverse interlocks closed in proper direction. Throttle open past IDLE. 117 motor switch closed (MU). V contacts closed, V relay closed. SP2 interlocks closed, SP2 contactor closed.
RC	Reverse-Current Relay	Closes its contacts when auxiliary generator voltage exceeds battery voltage enough to charge battery. Auxiliary-generator fuse 103 good. B interlocks closed, B contactor open. Auxiliary-generator field fuse 104 good. X voltage-regulating relay contacts closed.
S	Series Contactor	Battery switch 100 closed. Battery fuse 105 good. Control switch closed, fuse good. Throttle open past IDLE.

Device Symbol	Name	Contacts Necessary to Operate
S(Cont'd)	Series Contactor	Selector in any but OFF position. Reverser interlocks closed in proper direction. NOTE: Control air pressure at reverser must be normal (70 lb). SP1 interlocks closed, SP1 contactor open. NOTE: Control air pressure at S contactor must be normal (70 lb).
SP1	Series-Parallel Contactor	Selector in series-parallel or reduced-field position. Series holding switch 124, ON (MU). Motor-control switch 117 closed (MU). CR1 contacts closed, CR1 relay closed. GF interlocks closed, GF contactor open. SP1 stays closed through its own interlocks after GF closes. Air pressure at SP1 must be normal (70 lb).
SP2	Series-Parallel Contactor	S interlock closed, S contactor open. NOTE: Control air pressure at SP2 contactor must be normal (70 lb).
V	Transition Relay	SERIES TO SERIES-PARALLEL V contacts closed with: M1 interlock closed, M1 contactor open.

Device Symbol	Name	Contacts Necessary to Operate
V(Cont'd)	Transition Relay	GF interlock 5A-5B (15A-15 MU) closed, GF contactor open. SERIES-PARALLEL TO REDUCED FIELD V contacts closed with: M1 interlock closed, M1 contactor open. GF interlock 5A-5B (15-15A-MU) closed, GF contactor closed. REDUCED FIELD TO SERIES-PARALLEL V contacts open with: M1 interlock 5A-5B (15-15A-MU) open, M1 contactor closed. GF interlock closed, GF contactor closed. SERIES-PARALLEL TO SERIES (NON-AUTOMATIC) Close throttle to idle to make backward transition. V contacts open with: M1 interlock closed, M1 contactor open. GF interlock 5A-5B (15-15A-MU) open, GF contactor open. Open throttle. S contactor closes.

Device Symbol	Name	Contacts Necessary to Operate
WS1,WS2	Wheel-Slip Relay	No contacts involved. Either relay closes when the voltage across each armature of a pair of traction motors in series becomes unbalanced by wheels slipping.
X	Voltage Regulating Relay	Auxiliary-generator field fuse 104 good. Contacts are normally held closed by spring action when auxiliary generator is not generating. As voltage builds up, these regulating contacts open or close, one after another, to hold a set voltage.
- -	Reverser	Battery switch 100 closed. Battery fuse 105 good. Control switch closed,fuse good. Throttle open beyond IDLING. Selector in any but OFF position. Motor-control switch closed (MU). NOTE: Control air pressure must be normal at reverser (70 lb).
A	Aux. Gen. Field	Battery switch 100 closed. Battery fuse 105 good. Control push-button switch closed. RC relay and B contactor picked up. Fuse 104 good.

Device Symbol	Name	Contacts Necessary to Operate
	Controller Locking Coil (SU)	Contacts on voltage-regulating relay operative. Battery switch 100 closed. Battery fuse 105 good. Control switch closed,fuse good. Throttle switch closed (throttle open).
	Fuel-Pump Motor	Battery switch 100 closed. Battery fuse 105 good. Fuel-pump switch closed, fuse good.
116	Heater Fan Motor	Battery switch 100 closed. Battery fuse 105 good. B contactor closed. Heater switch closed, fuse good.
	Lighting and Headlight Circuits	Battery switch 100 closed. Battery fuse 105 good. Respective switches closed, fuses good.
	Overload Indicating Light	CL overload relay closed, because of generator overload in the series-parallel or reduced-field position.
118	Wheel-Slip Buzzer	WS1 or WS2 relay closed.
	Sander Magnet Valves(MU)	Reverser in forward or reverse. Control push-button switch closed. Forward or reverse interlock closed. Sander foot switch 122 closed.

Device Symbol	Device Name	Contacts Necessary to Operate
T1	Valve on Throttle Operating Mechanism	Throttle in 2-4-6 or 8th notch.
T2	Valve on Throttle Operating Mechanism	Throttle in 3-4-7 or 8th notch.
T3	Valve on Throttle Operating Mechanism	Throttle in 5-6-7 or 8th notch.

Transitions	How Made	Device Operation
Series to Series-Parallel	Automatically	V relay closes. CR1 relay closes and stays closed. GF contactor opens. V relay opens. SP1 contactor closes. S contactor opens. SP2 contactor closes. GF contactor closes.
Series-Parallel to Reduced Field	Automatically	V relay closes. M1 contactor closes. M2 contactor closes.
Reduced Field to Series-Parallel	Automatically	V relay opens. M1 contactor opens. M2 contactor opens.
Series-Parallel to Series (SU Operation)	Manually - Throttle closed to idle and selector turned to series when indicating lamp lights.	CR1 relay opens. SP1 contactor opens. SP2 contactor opens. GF contactor opens. S contactor closes. GF contactor closes.
Series-Parallel to Series (MU Operation)	Manually - Throttle closed to idle when indicating lamp lights.	Same as for single-unit operation.

TRANSITION INTERLOCKING

The purpose of the interlock contacts involved in the operation of the excitation and traction relays are:

(NOTE: Wire numbers in parenthesis apply to MULTIPLE-UNIT control units.)

1. GR relay contacts 8L-8H are in series with EF coil.

   a. If a ground occurs in the power circuits, the ground relay picks up, opens contactor EF, causing a decrease in main-generator voltage to prevent further damage to the equipment.

2. SP1 interlock contacts 8A-8B are in series with series contactor S coil.

   a. The SP1 interlock opens S contactor at the proper time in transferring from SERIES to SERIES-PARALLEL. It also prevents S contactor from closing before SP1 and SP2 drop out in backward transition from SERIES-PARALLEL to SERIES.

3. GF coil with the traction motors in SERIES has in series with it the following contacts:

   a. SP1 contacts 8A-8B (8A-8B) serve only to back up CR1 contacts 8C-8D (8C-8D), to prevent GF from closing through this circuit while in SERIES-PARALLEL.

   b. S contacts 8B-8C (8B-8C) prevent the closing of GF main-generator field contactor until after S has closed and the traction motors are connected to the generator in SERIES. This assures a smoother application of power to the traction motors.

   c. CR1 contacts 8C-8D (8C-8D) open GF to decrease the main-generator voltage in preparation for transition from SERIES to SERIES-PARALLEL.

This results in less arcing of the main contactors and a smoother transition.

   d. GS1 contacts 8D-8E (8D-8E) and GS2 contacts 8E-8F (8E-8F) prevent generator voltage from building up, unless both GS1 and GS2 open. Without this interlocking, the main-generator voltage could be put on the battery with disastrous results, if GS1 and GS2 should fail to open. Even if only one should remain closed, an undesirable high potential could be put on the battery and all of the 74-volt control circuits.

   e. GR contacts 8F-8G (8F-8G) decrease the main-generator voltage in case of a ground, thereby preventing an excessive flow of current through this fault.

4. GF coil, with the traction motors in SERIES-PARALLEL or REDUCED FIELD, has in series with it:

   a. CR1 contacts 2-2A (8J-65) in parallel with V relay contacts 2-2A (8J-6) so that after V relay contacts 2-2A (8J-6) close the CR1 relay, CR1 relay is held in by its own 2-2A (8J-65) contacts after V relay opens, and thus holds control voltage available to pick up SP1, SP2, and GF at the proper time.

   b. After CR1 contacts 8C-8D (8C-8D) have opened to open GF, the 2A-2B (8J-8K) contacts of GF close SP1.

   c. When SP1 closes, its 2A-2B (8J-8K) interlock closes to establish a holding circuit.

   d. After the 8A-8B contacts of SP1 open and cause S contactor to open, the 2B-2C (8K-8L) contacts on S close SP2. This sequence assures S being open before SP2 closes, preventing a short circuit on the generator.

e. With SP1 and SP2 closed, the traction motors are connected in SERIES-PARALLEL across the generator. SP2 contacts 2C-8D (8D-8L) close GF causing main-generator voltage to build up.

f. GS1 contacts 8D-8E (8D-8E) and GS2 contacts 8E-8F (8E-8F) prevent GF from closing and building up generator voltage, unless both GS1 and GS2 are open.

g. GR contacts 8F-8G (8F-8G) open GF to decrease the main-generator voltage in case of a ground on the generator or traction motors.

h. M1 and M2 coils have V contacts 3-3A (8M-8A) and SP2 contacts 3A-3B (8M-8N) in series with them.

j. SP2 normally-open interlock 3A-3B (8M-8N) prevents reduced-field contactors M1 and M2 from closing when V relay interlock 3-3A (8A-8M) closes to initiate the SERIES to SERIES-PARALLEL transfer. Before this transfer is completed, V relay opens. This occurs before SP2 interlock 3-3A (8M-8N) closes. This interlocking makes the closing of V relay interlock 3-3A (8A-8M) effective only in transferring from SERIES-PARALLEL to REDUCED FIELD.

TRANSITION RELAY V

Transition relay V, with the aid of CR1 relay, transfers the traction-motor connections automatically from SERIES to SERIES-PARALLEL at about 8 mph, from SERIES-PARALLEL to REDUCED FIELD at about 23 mph, and from REDUCED FIELD back to SERIES-PARALLEL at about 16 mph.

These transfers are made to fully utilize the output of the diesel engine. If the traction motors were left in SERIES above 8 mph, or in SERIES-PARALLEL above

23 mph, their characteristics and the generator characteristics would unload the diesel engine as the locomotive speed increased, though no harm would be done to any equipment. The governor would back off the fuel racks to put less fuel into the engine and the generator voltage would be somewhat higher than normal. Full diesel-engine power would not be utilized, even though the throttle were pulled all the way back.

The transfer from high-speed to low-speed connections restores full-field traction-motor operation, resulting in lower generator and motor currents than would be obtained at the same locomotive speed in REDUCED FIELD. When encountering an ascending grade the speed of the locomotive decreases and allows more current to flow in the motor, consequently more current flow from the main generator.

When locomotive speed has decreased to about 16 mph, transition relay V opens, opening the M1 and M2 contactors. This strengthens the traction-motor fields, decreases the motor armature and generator currents, and traction motors are then in SERIES-PARALLEL connection.

In SERIES-PARALLEL operation, the generator furnishes twice the current as is taken by any one motor because traction motors No. 1 and No. 2 are in parallel with motors No. 3 and No. 4. Further decrease in locomotive speed causes a still higher generator current and when this current becomes too high, transfer back to SERIES should be made. Transition relay V does not make this transfer; it must be made manually by operation of the controller handle.

The transition relay has an armature hinged at its center. The upper end of this armature is opposite the current coil of the relay. The contacts, one at the top and one at the bottom, are arranged so that both close when the upper end of the armature is closed by the voltage coil.

The voltage coil of the relay is connected, in series with resistor VR1, 3, 4, 5 and 6, across the generator and measures the current in the main generator.

Normally, with no voltage and current on the relay, its armature is held by a spring in its contact-open position. As the locomotive starts to move with traction motors in SERIES, the current is high and the voltage low. The current coil holds the relay contacts open. With increased speed, the motor and generator current decreases, weakening their hold-out effect on the relay, while the voltage simultaneously increases and strengthens its pull-in effect. When the ratio of voltage pull-in effect to the current hold-out effect increases to the operating point of the relay, its armature moves and closes both contacts.

A ratio of voltage to current closes the relay contacts. The relay closes at about the same locomotive speed (8 mph), regardless of throttle position.

The same action takes place when running in SERIES-PARALLEL and increasing in speed. The relay closes to transfer to REDUCED FIELD at about 23 mph.

The pick-up point of the relay, a ratio of generator current to voltage, can be adjusted by changing the resistance of either the voltage-coil resistor VR1 or the current-coil resistor VR7. To cause relay to pick up at a higher locomotive speed, increase VR1 resistance to weaken the voltage coil or decrease VR7 resistance to strengthen the current coil.

Resistors VR4, 5 and 6 are normally short-circuited out by an interlock on the main-generator field contactor GF when the locomotive is in operation. They are effective only during transition from SERIES to SERIES-PARALLEL.

When the main contacts of GF open to decrease main-generator voltage, its 5A-5B (15A-15B) interlock opens, inserting VR4, 5 and 6 in the voltage-coil circuits of the

V relay, causing it to open and to be ready to close again when conditions indicate the need to transfer from SERIES-PARALLEL to REDUCED FIELD.

Transfer back from REDUCED FIELD to SERIES-PARALLEL is required of relay V. When the reduced-field connection is made by the closing of M1 and M2 contactors, interlock 5A-5B (15A-15B) on M1 contactor opens to insert VR2 and VR3 in the voltage-coil circuit of V. In the series and series-parallel connections, these resistors are shorted out by M1 interlock. When they are inserted in the V voltage-coil circuit, they decrease the current flowing in the coil. Without this action, the relay would remain closed until the locomotive speed had dropped quite low. Inserting the VR2 and VR3 resistors allows the relay to open at about 16 mph.

No automatic transfer is made from SERIES-PARALLEL back to SERIES.

EXCITER OPERATION

The exciter is one-half of the GMG-139 and performs as a separate machine, and has its own separate circuits. The auxiliary generator, part of the GMG-139, supplies low-voltage power for operation of the control devices, lighting and charging the storage battery; the exciter supplies current to the shunt field of the traction generator, thereby controlling the output characteristics for traction purposes.

The exciter has a compound field winding. The series field is a differential or bucking winding, through which the main-generator load current passes. The shunt field receives exciting current partly from the battery, controlled by the R6-R8 portion of the EFR, and partly from its own armature, controlled by the R5-R6 portion of the same EFR.

The output of the exciter armature is delivered to the main field of the traction generator, therefore, the

characteristics of the main generator will be largely determined by the characteristic of the exciter. The exciter-field windings are so proportioned that when the locomotive is running at low speeds, the high currents required at that time by the traction motors, flowing through the differential field, will keep the generator voltage low. If the voltage were allowed to remain at a higher value at the high current, the generator would demand too much horsepower from the diesel engine.

As the current begins to decrease during acceleration, the voltage gradually increases, so that the main generator demands practically a constant amount of power from the diesel engine. As the locomotive speed continues to increase, the current in the differential field of the exciter gradually decreases and the excitation from the exciter shunt field predominates, producing the required higher voltage at the higher speeds and maintaining approximately a constant power demand on the diesel engine.

Decreasing the resistance of R5-R6 will tend to increase the voltage at the lower generator currents. Decreasing the resistance of R6-R8 will tend to increase the generator voltage at the high currents. To make proper adjustments, it is necessary to read the rpm, load amperes, and voltage of the main generator. No attempt should be made to adjust this unless instruments for making these measurements and trained personnel are available.

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